

COMPOSITIONS AND METHODS FOR ENHANCED BIOSTABILITY AND
ALTERED BIODISTRIBUTION OF OLIGONUCLEOTIDES IN MAMMALS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of (I)
5 application serial number 08/464,953, filed June 5, 1995,
which is a continuation-in-part of application serial number
08/117,363, filed September 3, 1993, which is a continuation-
in-part of application serial number PCT/US92/09196, filed
October 23, 1992 (now application serial number 08/211,882,
10 filed April 22, 1994), which is a continuation-in-part of
application serial number 07/782,374, filed October 24, 1991
(now abandoned), which is a continuation-in-part of (A)
application serial number 07/463,358, filed January 11, 1990
(now abandoned), and (B) application serial number
15 07/566,977, filed August 13, 1990 (now abandoned); (II)
application serial number 08/344,155, filed November 23,
1994, which is a continuation-in-part of application number
08/063,167, filed May 17, 1993 (now U.S. Patent No.
5,514,788), which is a continuation-in-part of application
20 number 08/007,997 (now U.S. Patent No. 5,591,623), filed
January 21, 1993, which is a continuation-in-part of
application number 07/939,855, filed September 2, 1992 (now
abandoned), which is a continuation-in-part of application
number 07/567,286, filed August 14, 1990 (now abandoned); and
25 (III) application serial number 08/731,299, filed October 4,
1996. The entire disclosures of each of these applications,
which are assigned to the assignee of this application, are
incorporated herein by reference.

FIELD OF THE INVENTION

This application is directed to oligonucleotides and oligonucleosides functionalized to include lipophilic moieties. Relative to their unfunctionalized parent
5 compounds, such lipophilic oligonucleotide conjugates have improved biostability and altered biodistribution in mammals. In one embodiment, such lipophilic oligonucleotide conjugates are used in a method of targeting antisense oligonucleotides to hepatic tissues and thereby preferentially modulating gene
10 expression in the liver and associated tissues of a mammal.

BACKGROUND OF THE INVENTION

Messenger RNA (mRNA) directs protein synthesis. Antisense methodology is the complementary hybridization of relatively short oligonucleotides to mRNA or DNA such that
15 the normal, essential functions of these intracellular nucleic acids are disrupted. Hybridization is the sequence-specific hydrogen bonding via Watson-Crick base pairs of oligonucleotides to RNA or single-stranded DNA. Such base pairs are said to be complementary to one another.

20 The naturally occurring events that provide the disruption of the nucleic acid function, discussed by Cohen in *Oligonucleotides: Antisense Inhibitors of Gene Expression*, CRC Press, Inc., Boca Raton, Florida (1989) are thought to be of two types. The first, hybridization arrest, denotes the
25 terminating event in which the oligonucleotide inhibitor binds to the target nucleic acid and thus prevents, by simple steric hindrance, the binding of essential proteins, most often ribosomes, to the nucleic acid. Methyl phosphonate oligonucleotides (Miller, et al., *Anti-Cancer Drug Design*,
30 1987, 2, 117) and α -anomer oligonucleotides are examples of antisense agents which are thought to disrupt nucleic acid function by hybridization arrest.

The second type of terminating event for antisense oligonucleotides involves the enzymatic cleavage of the
35 targeted RNA by intracellular RNase H. A 2'-deoxyribofuranosyl oligonucleotide or oligonucleotide analog

hybridizes with the targeted RNA and this duplex activates the RNase H enzyme to cleave the RNA strand, thus destroying the normal function of the RNA. Phosphorothioate oligonucleotides are the most prominent example of an antisense agent that operates by this type of antisense terminating event.

Considerable research is being directed to the application of oligonucleotides and oligonucleotide analogs as antisense agents for diagnostics, research reagents and potential therapeutic purposes. At least for therapeutic purposes, and for research purposes involving whole cells, tissues or animals, the antisense oligonucleotides and oligonucleotide analogs must be transported across cell membranes or otherwise taken up by cells in order to exhibit activity. One method for generally increasing membrane or cellular transport is by the attachment of a pendant lipophilic group. More specifically, Ramirez et al. (*J. Am. Chem. Soc.*, 1982, 104, 5483) introduced the phospholipid group 5'-O-(1,2-di-O-myristoyl-sn-glycero-3-phosphoryl) into the dimer TpT independently at the 3' and 5' positions. Subsequently Shea et al. (*Nuc. Acids Res.*, 1990, 18, 3777) disclosed oligonucleotides having a 1,2-di-O-hexyldecyl-rac-glycerol group linked to a 5'-phosphate on the 5'-terminus of the oligonucleotide. Certain of the Shea et. al. authors also disclosed these and other compounds in patent application PCT/US90/01002. A further glucosyl phospholipid was disclosed by Guerra et al. (*Tetrahedron Letters*, 1987, 28, 3581).

In other work, a cholesteryl group was attached to the inter-nucleotide linkage between the first and second nucleotides (from the 3' terminus) of an oligonucleotide. This work is disclosed in United States Patent No. 4,958,013 and further by Letsinger et al. (*Proc. Natl. Acad. Sci. USA*, 1989, 86, 6553). The aromatic intercalating agent anthraquinone was attached to the 2' position of a sugar fragment of an oligonucleotide as reported by Yamana et al. (*Bioconjugate Chem.*, 1990, 1, 319). The same researchers

placed pyrene-1-methyl at the 2' position of a sugar (Yamana et al., *Tetrahedron Lett.*, 1991, 32, 6347).

Lemairte et al. (*Proc. Natl. Acad. Sci. USA*, 1986, 84, 648) and Leonetti et al. (*Bioconjugate Chem.*, 1990, 1, 149). The 3' terminus of the oligonucleotides each include a 3'-terminal ribose sugar moiety. The poly(L-lysine) was linked to the oligonucleotide via periodate oxidation of this terminal ribose followed by reduction and coupling through a N-morpholine ring. Oligonucleotide-poly(L-lysine) conjugates are described in European Patent application 87109348.0. In this instance the lysine residue was coupled to a 5' or 3' phosphate of the 5' or 3' terminal nucleotide of the oligonucleotide. A disulfide linkage has also been utilized at the 3' terminus of an oligonucleotide to link a peptide to the oligonucleotide (Corey et al., *Science*, 1987, 238, 1401; Zuckermann, et al., *J. Am. Chem. Soc.*, 1988, 110, 1614; and Corey et al., *J. Am. Chem. Soc.*, 1989, 111, 8524).

Nelson et al. (*Nuc. Acids Res.*, 1989, 17, 7187) describe a linking reagent for attaching biotin to the 3'-terminus of an oligonucleotide. This reagent, N-Fmoc-O-DMT-3-amino-1,2-propanediol is now commercially available from Clontech Laboratories (Palo Alto, CA) under the name 3'-Amine on. It is also commercially available under the name 3'-Amino-Modifier reagent from Glen Research Corporation (Sterling, VA). This reagent was also utilized to link a peptide to an oligonucleotide as reported by Judy et al. (*Tetrahedron Letters*, 1991, 32, 879). A similar commercial reagent (actually a series of such linkers having various lengths of polymethylene connectors) for linking to the 5'-terminus of an oligonucleotide is 5'-Amino-Modifier C6. These reagents are available from Glen Research Corporation (Sterling, VA). These compounds or similar ones were utilized by Krieg et al. (*Antisense Research and Development*, 1991, 1, 161) to link fluorescein to the 5'-terminus of an oligonucleotide. Other compounds of interest have also been linked to the 3'-terminus of an oligonucleotide. Asseline et al. (*Proc. Natl. Acad. Sci. USA*, 1984, 81, 3297) described

linking acridine on the 3'-terminal phosphate group of an poly (Tp) oligonucleotide via a polymethylene linkage. Haralambidis et al. (*Tetrahedron Letters*, 1987, 28, 5199) report building a peptide on a solid state support and then
5 linking an oligonucleotide to that peptide via the 3' hydroxyl group of the 3' terminal nucleotide of the oligonucleotide. Chollet (*Nucleosides & Nucleotides*, 1990, 9, 957) attached an Aminolink 2 (Applied Biosystems, Foster City, CA) to the 5' terminal phosphate of an oligonucleotide.
10 Chollet then used the bifunctional linking group SMPB (Pierce Chemical Co., Rockford, IL) to link an interleukin protein to the oligonucleotide.

An EDTA iron complex has been linked to the 5 position of a pyrimidine nucleoside as reported by Dreyer et al.
15 (*Proc. Natl. Acad. Sci. USA*, 1985, 82, 968). Fluorescein has been linked to an oligonucleotide in the same manner as reported by Haralambidis, et al. (*Nucleic Acid Research*, 1987, 15, 4857) and biotin in the same manner as described in PCT application PCT/US/02198. Fluorescein, biotin and pyrene
20 were also linked in the same manner as reported by Telser et al. (*J. Am. Chem. Soc.*, 1989, 111, 6966). A commercial reagent, Amino-Modifier-dT, from Glen Research Corporation (Sterling, VA) can be utilized to introduce pyrimidine nucleotides bearing similar linking groups into
25 oligonucleotides.

Cholic acid linked to EDTA for use in radioscintigraphic imaging studies was reported by Betebenner et al. (*Bioconjugate Chem.*, 1991, 2, 117); however, it is not known to link cholic acid to nucleosides, nucleotides or
30 oligonucleotides.

Despite these efforts and other research in the field, it is not known in the art to use lipophilic conjugation to alter the pharmacodynamic properties of an antisense compound, i.e., an agent that works via a nucleotide
35 sequence-dependent antisense mechanism.

OBJECTS OF THE INVENTION

It is one object of this invention to provide oligonucleotides and oligonucleosides functionalized to include lipophilic moieties in order to produce lipophilic oligonucleotide and oligonucleoside conjugates which, relative to their unfunctionalized parent compounds, have improved biostability and altered biodistribution in mammals.

It is a further object of the invention to provide methods of modulating gene expression in cells, tissue(s) or organ(s) of a mammal using the lipophilic oligonucleotide and oligonucleoside conjugates of the invention.

It is a particular object of the invention to provide compositions for and methods of targeting antisense oligonucleotides to hepatic tissues and thereby preferentially modulating gene expression in the liver and associated tissues of a mammal.

BRIEF DESCRIPTION OF THE INVENTION

These and other objects are satisfied by the present invention, which provides oligonucleotides and oligonucleosides functionalized to include lipophilic moieties. In one aspect, the invention provides nucleosides having base portions and ribofuranosyl sugar portions. Such nucleosides bear at a 2'-O-position, a 3'-O-position, or a 5'-O-position a substituent having formula:



where:

R_A is alkyl having from 1 to about 10 carbon atoms or R_A is $(CH_2-CH_2-Q)_x$;

R_{1a} and R_{1b} , independently, are H, R_A , R_2 , or an amine protecting group or have formula $C(X)-R_2$, $C(X)-R_A-R_2$, $C(X)-Q-R_A-R_2$, $C(X)-Q-R_2$;

R_2 includes a steroid molecule, a reporter molecule, a lipophilic molecule, a reporter enzyme, a peptide, a protein, or has formula $-Q-(CH_2CH_2-Q)_x-R_3$;

X is O or S;

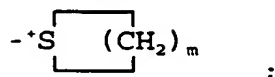
each Q is, independently, is NH, O, or S;

x is 1 to about 200;

R_3 is H, R_A , $C(O)OH$, $C(O)OR_A$, $C(O)R_4$, R_A-N_3 , R_A-NH_2 , or R_A-SH ; and

R_4 is Cl, Br, I, SO_2R_5 or has structure:

5



m is 2 to 7; and

10 R_5 is alkyl having 1 to about 10 carbon atoms.

In another aspect, the invention provides oligonucleotides and oligonucleosides comprising a plurality of linked nucleosides, wherein each nucleoside includes a ribofuranosyl sugar portion and a base portion and at least one (preferably
15 more than one) of the nucleosides bears at a 2'-O-position, a 3'-O-position, or a 5'-O-position a substituent having formula $-R_A-N(R_{1a})(R_{1b})$.

In another aspect the invention provides methods for preparing oligonucleotides and oligonucleosides comprising
20 the steps of contacting nucleosides according to the invention for a time and under reaction conditions effective to form a covalent bond therebetween. In preferred embodiments, at least one of the nucleosides bears a phosphoramidate group at its 2'-O-position or at its 3'-O-
25 position.

In other embodiments, compounds according to the invention are prepared by contacting a nucleoside, oligonucleotide or oligonucleoside with derivatizing reagents. For example, a nucleoside, oligonucleotide or
30 oligonucleoside bearing a 2'-hydroxy group, a 3'-hydroxy group, or a 5'-hydroxy group under basic conditions with a compound having formula $L_1-R_A-N(R_{1a})(R_{1b})$ wherein L_1 is a leaving group such as a halogen and at least one of R_{1a} and R_{1b} is an amine protecting group.

35 The present invention also provides methods for inhibiting the expression of particular genes in the cells of an organism, comprising administering to said organism a compound according to the invention. Also provided are methods for inhibiting transcription and/or replication of

particular genes or for inducing degradation of particular regions of double stranded DNA in cells of an organism by administering to said organism a compound of the invention. Further provided are methods for killing cells or virus by
5 contacting said cells or virus with a compound of the invention. The compound can be included in a composition that further includes an inert carrier for the compound.

BRIEF DESCRIPTION OF THE DRAWINGS

The numerous objects and advantages of the present
10 invention may be better understood by those skilled in the art by reference to the accompanying figures, in which:

Figure 1 shows the dose response for oligonucleotide inhibition of MDR1 message in transfected 3T3 cells. The MDR-3T3 cells were treated with 50 nM, 100 nM, 250 nM, 500
15 nM or 1000 nM concentrations of ISIS 5995 oligomer, or 1000 nM of ISIS 10221 scrambled control oligomer, for 24 hours in the presence of LIPOFECTIN[®]. RNA was isolated, separated and probed with a 1.0 kB MDR1 cDNA fragment. The same blots were stripped and probed with a beta-actin probe to ensure uniform
20 loading. Levels of MDR1 mRNA from the blots were quantitated using a PHOSPHORIMAGER[™] (Molecular Dynamics, Sunnyvale, CA) and the values are expressed as percent of control. The results represent mean values and standard errors of the mean from 5 independent experiments. Filled diamond, ISIS 5995;
25 closed diamond, ISIS 10221.

Figure 2 shows the effect of cholesterol-conjugated phosphothioate oligonucleotides on P-glycoprotein surface expression. MDR 3T3 cells were treated with various concentrations of oligonucleotides ISIS 11073 (5'-cholesterol
30 5995), or ISIS 12064 (5'-cholesterol 10221; scrambled control) for 48 hours in serum free medium. The cells were recovered and stained with an anti-P-glycoprotein monoclonal antibody directed against a surface epitope, followed by a phycoerythrin-conjugated second antibody. The level of cell
35 surface fluorescence in viable cells was quantitated using a flow cytometer; light scatter parameters were set so as to

exclude non-viable cells. A parallel experiment was done with cells treated with oligonucleotides ISIS 5995 and ISIS 10221 at 1 μ m , in the presence of LIPOFECTIN^R. The data are presented as percent inhibition of P-glycoprotein expression, 5 with the 100% level taken as that for untreated MDR 3T3 cells. The results represent means and standard errors for 6 determinations. Filled diamonds, ISIS 11073 (cholesterol-conjugated ISIS 5995); filled circles, ISIS 12064 (cholesterol-conjugated ISIS 10221; scrambled control); open 10 diamonds, ISIS 5995; open triangles, ISIS 10221.

Figure 3 shows the results of experiments in which cells treated as described in Figure 2 were analyzed for Rhodamine 123 uptake. Subsequent to oligonucleotide treatment the cells were washed and then exposed to 1 ug/ml 15 Rh 123 in serum free medium at 37°C. After 1 hour the cells were washed and the amount of Rh 123 accumulated by viable cells was quantitated using a flow cytometer. The results represent means and standard errors for 3 determinations. Symbols, as in Figure 2.

20 Figure 4 shows the uptake and intracellular distribution of effect of cholesterol-conjugated phosphothioate MDR1 oligonucleotides. MDR-3T3 cells were treated with 1 μ m ISIS 13331 (5'-FITC, 3'-cholesterol 5995), or with 1 μ m ISIS 13434 (5'-FITC 5995) for 2 hours in serum 25 free medium at 37°C. Cells were harvested and the fluorescence profiles were determined using a flow cytometer; light scatter parameters were set so as to exclude non-viable cells. Solid line, free ISIS 13434 (5'-FITC 5995); dashed line, ISIS 13434 with Lipofectin^R; dotted line, ISIS 13331 30 (5'-FITC, 3'-cholesterol 5995).

Figure 5 shows the uptake and intracellular distribution of effect of cholesterol-conjugated phosphothioate MDR1 oligonucleotides of cells treated as in Figure 4 but for 18 hours instead of 2 hours. The 18 hour 35 treatment with LIPOFECTIN^R resulted in some cells with very high levels (above 10⁴ units) of fluorescence; these were

accumulated in one channel and are shown as a vertical line at the right hand margin of the plot.

Figure 6 shows modulation of P-glycoprotein (PGP) expression by 2'-methoxyethoxy oligonucleotides as determined by flow cytometry essentially as described in Figure 2. Open boxes, ISIS 13753 (2'-methoxyethoxy derivative of ISIS 10221); closed circles, ISIS 13755 (2'-methoxyethoxy derivative of ISIS 5998); closed boxes, ISIS 13758 (2'-methoxyethoxy derivative of ISIS 5995).

Figure 7 is a graph showing mouse plasma concentrations of a control compound and two of the compounds of the invention. The plasma concentration is plotted versus time.

Figure 8 is a three dimensional graph showing distribution of a control compound, ISIS 3082, among various tissues in the mouse. Specific tissues are shown on one axis, time on a second axis and percent of dose on the third axis. The compound was delivered by intravenous injection.

Figure 9 is a three dimensional graph showing distribution of a compound of the invention, ISIS 9047, among various tissues in the mouse. Specific tissues are shown on one axis, time on a second axis and percent of dose on the third axis. The compound was delivered by intravenous injection.

Figure 10 is a three dimensional graph showing distribution of a further compound of the invention, ISIS 8005, among various tissues in the mouse. Specific tissues are shown on one axis, time on a second axis and percent of dose on the third axis. The compound was delivered by intravenous injection.

Figure 11 shows data demonstrating the modulation of ICAM-1 mRNA levels in the livers of Balb/c mice by cholesterol-conjugated oligonucleotides. Terms: BASAL, untreated cells; LPS, lipopolysaccharide (ICAM-1 inducing agent); ISIS 3082, antisense phosphorothioate oligonucleotide targeted to mouse ICAM1 sequences; ISIS 8005, 5'-cholesterol conjugate of ISIS 3082; ISIS 13293, 5'-cholesterol-conjugated

scrambled control oligonucleotide for ISIS 8005; the suffix "-30" indicates the dose (30 mg/kg) of oligonucleotide.

Figure 12 shows that the 5'-cholesterol ISIS 3082 analog (ISIS 8005) has no effect on c-raf and PECAM-1 mRNA levels in the murine liver. Terms: basal, untreated cells; lps, lipopolysaccharide (ICAM-1 inducing agent); ISIS 8005, 5'-cholesterol conjugated phosphorothioate antisense oligonucleotide targeted to mouse ICAM-1; ISIS 13293, 5'-cholesterol-conjugated scrambled control oligonucleotide for
10 ISIS 8005; the suffix "-10" indicates the dose (10 mg/kg) of oligonucleotide.

Figure 13 shows that the 5'-cholesterol ISIS 3082 analog (ISIS 8005) has little effect on ICAM-1 levels in murine lungs. Terms: BASAL, untreated cells; LPS,
15 lipopolysaccharide (ICAM-1 inducing agent); ISIS 3082, antisense phosphorothioate oligonucleotide targeted to mouse ICAM1 sequences; ISIS 8005, 5'-cholesterol conjugate of ISIS 3082; ISIS 13293, 5'-cholesterol-conjugated scrambled control oligonucleotide for ISIS 8005; the suffix "-30" indicates the
20 dose (30 mg/kg) of oligonucleotide.

Figure 14 shows the histology of reversal of LPS-mediated ICAM-1 induction by cholesterol-conjugated antisense oligonucleotides.

Figure 15 shows that Balb/c mouse liver ICAM-1 mRNA
25 levels can be modulated by a 3'-cholesterol-conjugated antisense oligonucleotide. Terms: basal, untreated cells; lps, lipopolysaccharide (ICAM-1 inducing agent); ISIS 9388, 3'-cholesterol conjugated phosphorothioate antisense oligonucleotide targeted to mouse ICAM-1; ISIS 13293, 5'-
30 cholesterol-conjugated scrambled control oligonucleotide for ISIS 8005; ISIS 6777, control oligonucleotide targeted to VCAM-1; the suffixes "-1", "-10" and "-20" indicate the dose (1, 10 or 10 mg/kg, respectively) of oligonucleotide.

DETAILED DESCRIPTION OF THE INVENTION

35 This invention provides nucleosides, oligonucleotides and oligonucleosides functionalized to include lipophilic

moieties in order to produce lipophilic oligonucleotide and oligonucleoside conjugates which, relative to their unfunctionalized parent compounds, have improved biostability and altered biodistribution in mammals. The nucleoside subunits can be "natural" or "synthetic" moieties. Each nucleoside is formed from a naturally occurring or synthetic base and a naturally occurring or synthetic pentofuranosyl sugar group.

The term "oligonucleotide" refers to a polynucleotide formed from a plurality of linked nucleotide units. The nucleotide units each include a nucleoside unit. In the context of this invention, the term "oligonucleoside" refers to a plurality of nucleoside units that are linked together. In a generic sense, since each nucleotide unit of an oligonucleotide includes a nucleoside therein, the term "oligonucleoside" can be considered to be inclusive of oligonucleotides (*i.e.*, nucleosides linked together via phosphate linking groups). In a further sense, the term "oligonucleoside" also refers to a plurality of nucleosides that are linked together via linkages other than phosphate linkages. The term "oligonucleoside" thus effectively includes naturally occurring species or synthetic species formed from naturally occurring subunits. For brevity, the term "oligonucleoside" will be used as encompassing both phosphate linked (oligonucleotides) and non-phosphate linked polynucleoside species.

Oligonucleosides according to the invention also can include modified subunits. Representative modifications include modification of a heterocyclic base portion of a nucleoside or a sugar portion of a nucleoside. Exemplary modifications are disclosed in the following United States Patent Applications: Serial No. 07/835,932, filed March 5, 1992, now U.S. Patent No. 5,670,633, entitled Sugar Modified Oligonucleotides That Detect And Modulate Gene Expression; Serial No. 558,663, filed July 27, 1990, now U.S. patent No. 5,138,045, entitled Novel Polyamine Conjugated Oligonucleotides; Serial No. 558,806, filed July 27, 1991,

entitled Nuclease Resistant Pyrimidine Modified Oligonucleotides that Detect and Modulate Gene Expression and Serial No. PCT/US91/00243, filed January 11, 1991, entitled Compositions and Methods for Detecting and Modulating RNA Activity. Teachings regarding the synthesis of particular modified oligonucleotides may also be found in the following U.S. patents or pending patent applications, each of which is commonly assigned with this application: U.S. Patents Nos. 5,138,045 and 5,218,105, drawn to polyamine conjugated oligonucleotides; U.S. Patent No. 5,212,295, drawn to monomers for the preparation of oligonucleotides having chiral phosphorus linkages; U.S. Patents Nos. 5,378,825 and 5,541,307, drawn to oligonucleotides having modified backbones; U.S. Patent No. 5,386,023, drawn to backbone modified oligonucleotides and the preparation thereof through reductive coupling; U.S. Patent No. 5,457,191, drawn to modified nucleobases based on the 3-deazapurine ring system and methods of synthesis thereof; U.S. Patent No. 5,459,255, drawn to modified nucleobases based on N-2 substituted purines; U.S. Patent No. 5,521,302, drawn to processes for preparing oligonucleotides having chiral phosphorus linkages; U.S. Patent No. 5,539,082, drawn to peptide nucleic acids; U.S. Patent No. 5,554,746, drawn to oligonucleotides having β -lactam backbones; U.S. Patent No. 5,571,902, drawn to methods and materials for the synthesis of oligonucleotides; U.S. Patent No. 5,578,718, drawn to nucleosides having alkylthio groups, wherein such groups may be used as linkers to other moieties attached at any of a variety of positions of the nucleoside; U.S. Patents Nos. 5,587,361 and 5,599,797, drawn to oligonucleotides having phosphorothioate linkages of high chiral purity; U.S. Patent No. 5,506,351, drawn to processes for the preparation of 2'-O-alkyl guanosine and related compounds, including 2,6-diaminopurine compounds; U.S. Patent No. 5,587,469, drawn to oligonucleotides having N-2 substituted purines; U.S. Patent No. 5,587,470, drawn to oligonucleotides having 3-deazapurines; U.S. Patents Nos. 5,223,168, issued June 29, 1993, and 5,608,046, both drawn to

conjugated 4'-desmethyl nucleoside analogs; U.S. Patent Nos. 5,602,240, and 5,610,289, drawn to backbone modified oligonucleotide analogs; and U.S. patent application Serial No. 08/383,666, filed February 3, 1995, and U.S. Patent No. 5,459,255, drawn to, *inter alia*, methods of synthesizing 2'-fluoro-oligonucleotides.

The term oligonucleoside thus refers to structures that include modified portions, be they modified sugar moieties or modified base moieties, that function similarly to natural bases and natural sugars. Representative modified bases include deaza or aza purines and pyrimidines used in place of natural purine and pyrimidine bases; pyrimidines having substituent groups at the 5 or 6 position; and purines having altered or replacement substituent groups at the 2, 6 or 8 positions. Representative modified sugars include carbocyclic or acyclic sugars, sugars having substituent groups at their 2' position, and sugars having substituents in place of one or more hydrogen atoms of the sugar. Other altered base moieties and altered sugar moieties are disclosed in United States Patent 3,687,808 and PCT application PCT/US89/02323.

Altered base moieties or altered sugar moieties also include other modifications consistent with the spirit of this invention. Such oligonucleosides are best described as being structurally distinguishable from yet functionally interchangeable with naturally occurring or synthetic wild type oligonucleotides. All such oligonucleosides are comprehended by this invention so long as they function effectively to mimic the structure of a desired RNA or DNA strand.

For use in antisense methodology, the oligonucleosides of the invention preferably comprise from about 10 to about 30 subunits. It is more preferred that such oligonucleosides comprise from about 15 to about 25 subunits. As will be appreciated, a subunit is a base and sugar combination suitably bound to adjacent subunits through, for example, a phosphorus-containing (e.g., phosphodiester) linkage or some

other linking moiety. The nucleosides need not be linked in any particular manner, so long as they are covalently bound. Exemplary linkages are those between the 3'- and 5'-positions or 2'- and 5'-positions of adjacent nucleosides. Exemplary
5 linking moieties are disclosed in the following references: Beaucage, et al., *Tetrahedron*, 1992, 48, 2223 and references cited therein; and United States Patents and applications: serial No. 07/703,619, filed May 21, 1991 (now U.S. Patent No. 5,378,825); Serial No. 07/903,160, filed June 24, 1992
10 (now U.S. Patent No. 5,623,070); serial No. 039,979, filed March 20, 1993 (currently pending as continuation application serial No. 08/317,289, filed October 3, 1994); Serial No. 08/039,846, filed March 30, 1993 and serial No. 08/392,675 filed February 23, 1995, (now U.S. Patent No. 5,677,437 ;
15 and serial No. 08/040,933, filed March 31, 1993 (now U.S. Patent No. 5,618,704). Each of the foregoing Patents or applications is assigned to the assignee of this invention, and the disclosure of each is incorporated herein by reference.

20 It is preferred that the RNA or DNA portion which is to be modulated using oligonucleosides of the invention be preselected to comprise that portion of DNA or RNA which codes for the protein whose formation or activity is to be modulated. The targeting portion of the composition to be
25 employed is, thus, selected to be complementary to the preselected portion of DNA or RNA, that is, to be an antisense oligonucleoside for that portion.

In accordance with one preferred embodiment of this invention, the compounds of the invention hybridize to mRNA
30 encoding ICAM-1 (intercellular adhesion molecule 1). ICAM-1 is a cell surface glycoprotein expressed primarily in endothelial cells that binds other cells, such as neutrophils, expressing cell surface antigens such as LFA-1 (Kishimoto et al., *Adv. Immunol.*, 1989, 46, 149). Several
35 lines of experimentation indicate that ICAM-1 plays an important role during various inflammatory responses (Bochner et al., *J. Exp. Med.*, 1991, 173, 1553; Carlos et al., *Blood*,

1991, 77, 2266). By modulating such responses according to the compositions and methods of the present invention, undesirable inflammatory responses are mediated. In another preferred embodiment of the invention, the compounds of the invention hybridize to MDR1 (multidrug resistance) mRNA encoding a membrane protein (P-glycoprotein) that functions as an ATP driven efflux pump. Hyperproliferative cells may become resistant to anticancer agents due to an overabundance of one or more nucleic acids (i.e., mRNA or DNA) encoding one or more such MDR proteins. By modulating this resistance according to the compositions and methods of the present invention, resistant cells are resensitized to such anticancer agents. Accordingly, the compositions and methods of the invention act to enhance the treatment of abnormal cell proliferation and tumor formation with anticancer agents. In further embodiments of the invention, the compounds of the invention hybridize to HIV mRNA encoding the tat protein, or to the TAR region of HIV mRNA. Other preferred compounds are complementary to sequences for herpes, papilloma and other viruses, or to sequences corresponding to cellular oncogenes, mediators of the immune response of an animal and other host-encoded functions.

The nucleosides and oligonucleosides of the invention can be used in diagnostics, therapeutics and as research reagents and kits. They can be used in pharmaceutical compositions by including a suitable pharmaceutically acceptable diluent or carrier. They further can be used for treating organisms having a disease characterized by the undesired production of a protein. The organism should be contacted with an oligonucleotide having a sequence that is capable of specifically hybridizing with a strand of nucleic acid coding for the undesirable protein. Treatments of this type can be practiced on a variety of organisms ranging from unicellular prokaryotic and eukaryotic organisms to multicellular eukaryotic organisms. Any organism that utilizes DNA-RNA transcription or RNA-protein translation as a fundamental part of its hereditary, metabolic or cellular

control is susceptible to therapeutic and/or prophylactic treatment in accordance with the invention. Seemingly diverse organisms such as bacteria, yeast, protozoa, algae, all plants and all higher animal forms, including warm-blooded animals, can be treated. Further, each cell of multicellular eukaryotes can be treated since they include both DNA-RNA transcription and RNA-protein translation as integral parts of their cellular activity. Many of the organelles (e.g., mitochondria and chloroplasts) of eukaryotic cells also include transcription and translation mechanisms. Thus, single cells, cellular populations or organelles can also be included within the definition of organisms that can be treated with therapeutic or diagnostic oligonucleotides. As used herein, therapeutics is meant to include the eradication of a disease state, by killing an organism or by control of erratic or harmful cellular growth or expression. The invention is also drawn to the administration of biologically active oligonucleotides having biological activity to cultured cells, isolated tissues and organs and animals. By being "biologically active," it is meant that the oligonucleotide functions to modulate the expression of one or more genes in cultured cells, isolated tissues or organs and/or animals. Such modulation can be achieved by an antisense oligonucleotide by a variety of mechanisms known in the art, including but not limited to transcriptional arrest; effects on RNA processing (capping, polyadenylation and splicing) and transportation; enhancement of cellular degradation of the target nucleic acid; and translational arrest (Crooke et al., *Exp. Opin. Ther. Patents*, 1996, 6:855).

The formulation of therapeutic compositions and their subsequent administration is believed to be within the skill of those in the art. In general, for therapeutics, a patient in need of such therapy is administered an oligonucleotide in accordance with the invention, commonly in a pharmaceutically acceptable carrier, in doses ranging from 0.01 μ g to 100 g per kg of body weight depending on the age of the patient and

the severity of the disorder or disease state being treated. Further, the treatment regimen may last for a period of time which will vary depending upon the nature of the particular disease or disorder, its severity and the overall condition
5 of the patient, and may extend from once daily to once every 20 years. Following treatment, the patient is monitored for changes in his/her condition and for alleviation of the symptoms of the disorder or disease state. The dosage of the oligonucleotide may either be increased in the event the
10 patient does not respond significantly to current dosage levels, or the dose may be decreased if an alleviation of the symptoms of the disorder or disease state is observed, or if the disorder or disease state has been ablated.

In some cases it may be more effective to treat a
15 patient with an oligonucleotide of the invention in conjunction with other traditional therapeutic modalities in order to increase the efficacy of a treatment regimen. In the context of the invention, the term "treatment regimen" is meant to encompass therapeutic, palliative and prophylactic
20 modalities. Following successful treatment, it may be desirable to have the patient undergo maintenance therapy to prevent the recurrence of the disease state, wherein the oligonucleotide is administered in maintenance doses, ranging from 0.01 μ g to 100 g per kg of body weight, once or more
25 daily, to once every 20 years.

The pharmaceutical compositions of the present invention may be administered in a number of ways depending upon whether local or systemic treatment is desired and upon the area to be treated. Administration may be topical
30 (including ophthalmic, vaginal, rectal, intranasal, transdermal), oral or parenteral. Parenteral administration includes intravenous drip, subcutaneous, intraperitoneal or intramuscular injection, or intrathecal or intraventricular administration.

35 Formulations for topical administration may include transdermal patches, ointments, lotions, creams, gels, drops, suppositories, sprays, liquids and powders. Conventional

pharmaceutical carriers, aqueous, powder or oily bases, thickeners and the like may be necessary or desirable. Coated condoms, gloves and the like may also be useful.

Compositions for oral administration include powders
5 or granules, suspensions or solutions in water or non-aqueous media, capsules, sachets or tablets. Thickeners, flavoring agents, diluents, emulsifiers, dispersing aids or binders may be desirable.

Compositions for parenteral, intrathecal or
10 intraventricular administration may include sterile aqueous solutions which may also contain buffers, diluents and other suitable additives.

Dosing is dependent on severity and responsiveness of the disease state to be treated, with the course of treatment
15 lasting from several days to several months, or until a cure is effected or a diminution of the disease state is achieved. Optimal dosing schedules can be calculated from measurements of drug accumulation in the body of the patient. Persons of
ordinary skill can easily determine optimum dosages, dosing
20 methodologies and repetition rates. Optimum dosages may vary depending on the relative potency of individual oligonucleotides, and can generally be estimated based on EC_{50} s found to be effective in *in vitro* and *in vivo* animal models. In general, dosage is from 0.01 μ g to 100 g per kg
25 of body weight, and may be given once or more daily, weekly, monthly or yearly, or even once every 2 to 20 years.

In one aspect, the present invention is directed to nucleosides and oligonucleosides that bear at least one amine-containing substituent at a position. Such
30 substituents preferably have formula $-R_A-N(R_{1A})(R_{1B})$ and are appended at 2'-O-, 3'-O-, and/or 5'-O-positions.

Each R_A according to the invention is an alkyl moiety independently selected to having 1 to about 10 carbon atoms
35 or R_A is a polyether, a polythioether or polyalkylamine. The term "alkyl" is intended to include straight chain and

branched hydrocarbons. The preferred length of these hydrocarbons is 1 to about 7 carbon atoms.

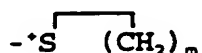
R_{1a} and R_{1b} according to the invention are H, R_A , R_2 , an amine protecting group, or have formula $C(X)-R_2$, $C(X)-R_A-R_2$,
5 $C(X)-Q-R_A-R_2$, $C(X)-Q-R_2$. Protecting groups are known *per se* as chemical functional groups that can be selectively appended to and removed from functionalities, such as amine groups. These groups are present in a chemical compound to render such functionality inert to chemical reaction
10 conditions to which the compound is exposed. See, e.g., Greene and Wuts, *Protective Groups in Organic Synthesis*, 2d edition, John Wiley & Sons, New York, 1991. Numerous amine protecting groups are known in the art, including, but not limited to: phthalimide (PHTH), trifluoroacetate (triflate),
15 allyloxycarbonyl (Alloc), benzyloxycarbonyl (CBz), chlorobenzyloxycarbonyl, t-butyloxycarbonyl (Boc), fluorenylmethoxycarbonyl (Fmoc), and isonicotinylloxycarbonyl (i-Noc) groups. (see, e.g., Veber and Hirschmann, et al., *J. Org. Chem.*, 1977, 42, 3286 and Atherton, et al., *The*
20 *Peptides*, Gross and Meienhofer, Eds, Academic Press; New York, 1983; Vol. 9 pp. 1- 38).

R_2 can include a steroid molecule, a reporter molecule, a lipophilic molecule, a reporter enzyme, a peptide, a protein (i.e., a substituent consisting essentially of same),
25 or a molecule having formula $-Q-(CH_2CH_2-Q)_x-R_3$. For the purposes of this invention the terms "reporter molecule" and "reporter enzyme" are inclusive of those molecules or enzymes that have physical or chemical properties that allow them to be identified in gels, fluids, whole cellular systems, broken
30 cellular systems and the like utilizing physical properties such as spectroscopy, radioactivity, colorimetric assays, fluorescence, and specific binding. Steroids include those chemical compounds that contain a perhydro-1,2-cyclopentanophenanthrene ring system. Proteins and peptides
35 are utilized in their usual sense as polymers of amino acids. Normally peptides comprise such polymers that contain a smaller number of amino acids per unit molecule than do the

proteins. Lipophilic molecules include naturally-occurring and synthetic aromatic and non-aromatic moieties such as fatty acids, esters, alcohols and other lipid molecules, substituted aromatic groups such as dinitrophenyl groups, cage structures such as adamantane and buckminsterfullerenes, and aromatic hydrocarbons such as benzene, perylene, phenanthrene, anthracene, naphthalene, pyrene, chrysene, and naphthacene.

Particularly useful as steroid molecules are the bile acids including cholic acid, deoxycholic acid and dehydrocholic acid; steroids including cortisone, digoxigenin, testosterone and cholesterol and even cationic steroids such as cortisone having a trimethylaminomethyl hydrazide group attached via a double bond at the 3 position of the cortisone rings. Particularly useful as reporter molecules are biotin, dinitrophenyl, and fluorescein dyes. Particularly useful as lipophilic molecules are alicyclic hydrocarbons, saturated and unsaturated fatty acids, waxes, terpenes and polyalicyclic hydrocarbons including adamantane and buckminsterfullerenes. Particularly useful as reporter enzymes are alkaline phosphatase and horseradish peroxidase. Particularly useful as peptides and proteins are sequence-specific peptides and proteins including phosphodiesterase, peroxidase, phosphatase and nuclease proteins. Such peptides and proteins include SV40 peptide, RNaseA, RNase H and Staphylococcal nuclease. Particularly useful as terpenoids are vitamin A, retinoic acid, retinal and dehydroretinol.

R_2 also can have formula $-Q-(CH_2CH_2-Q)_x-R_3$, where Q is O, S, or NH. Subscript x can be 1 to about 200, preferably about 20 to about 150, more preferably about 10 to about 50. Preferably, Q are selected to be O, such that R_2 constitutes a poly(ethyleneglycol) (PEG) group (i.e., $R_3 = H$) or a functionalized derivative thereof (e.g., $R_3 = C(O)Cl$). R_3 can be H, R_A , $C(O)OH$, $C(O)OR_A$, $C(O)R_A$, R_A-N_3 , R_A-NH_2 or R_A-SH where R_A is F, Cl, Br, I, SO_2R_5 or a small thio-containing heterocycle having structure:



where m is 2 to 7. Representative PEG-containing R₂ groups are disclosed by Ouchi, et al., *Drug Design and Discovery*, 1992, 9, 93, Ravasio, et al., *J. Org. Chem.*, 1991, 56, 4329, and Delgado et. al., *Critical Reviews in Therapeutic Drug Carrier Systems*, 1992, 9, 249.

Oligonucleosides according to the invention can be assembled in solution or through solid-phase reactions, for example, on a suitable DNA synthesizer utilizing nucleosides according to the invention and/or standard nucleotide precursors. The nucleosides and nucleotide precursors can already bear alkylamino groups or can be later modified to bear such groups.

In the former case, compounds according to the invention are prepared by, for example, reacting nucleosides bearing at least one free 2'-, 3'-, or 5'-hydroxyl group under basic conditions with a compound having formula L₁-(CH₂)_n-N(R_{1a})(R_{1b}) where L₁ is a leaving group and at least one of R_{1a} and R_{1b} is an amine protecting group. Displacement of the leaving group through nucleophilic attack of an oxygen anion produces the desired amine derivative. Leaving groups according to the invention include but are not limited to halogen, alkylsulfonyl, substituted alkylsulfonyl, arylsulfonyl, substituted arylsulfonyl, heterocyclosulfonyl or trichloroacetimidate. A more preferred group includes chloro, fluoro, bromo, iodo, p-(2,4-dinitroanilino)-benzenesulfonyl, benzenesulfonyl, methylsulfonyl (mesylate), p-methylbenzenesulfonyl (tosylate), p-bromobenzenesulfonyl, trifluoromethylsulfonyl (triflate), trichloroacetimidate, acyloxy, 2,2,2-trifluoroethanesulfonyl, imidazolesulfonyl, and 2,4,6-trichlorophenyl, with bromo being preferred.

Suitably protected nucleosides can be assembled into an oligonucleosides according to known techniques. See, e.g., Beaucage, et al., *Tetrahedron*, 1992, 48, 2223.

Oligonucleosides according to the invention also can be prepared by assembling an oligonucleoside and appending alkylamino functionality thereto. For example, oligonucleo-

sides having free hydroxyl groups can be assembled according to known techniques and then reacted with a reagent having formula $L_1-(CH_2)_n-N(R_{1a})(R_{1b})$. As will be recognized, however, greater selectivity can be achieved in terms of placement of
5 alkylamino functionality within an oligonucleoside by introducing such functionality, as discussed above, on selected nucleosides and then using both the selected nucleosides and other nucleosides to construct an oligonucleoside.

10 Once assembled, an oligonucleoside bearing one or more groups having formula $-R_A-N(R_{1a})(R_{1b})$ wherein at least one of R_{1a} and R_{1b} is a protecting group is treated with reagents effective to remove the protecting group. Once deprotected, the oligonucleoside can be contacted with electrophilic
15 moieties such as, for example, succinimidyl esters and other activated carboxylic acids including $C(=O)-O$ -succinimide and $C(=O)-O$ -pentafluorophenyl, isothiocyanates, sulfonyl chlorides, halacetamides, phospholipid carbocyclic acid active esters, o-phenanthroline-5-iodoacetamide, fluorescein
20 isothiocyanate, 1-pyrene butyric acid-N-hydroxy succinimide ester and carboxylic acid derivatives of PNA (carboxylic acid derivatives of peptide nucleic acids). Preferred electrophilic moieties include cholesteryl-3-hemisuccinate-N-hydroxy succinimide ester, pyrene-1-butyric acid-N-hydroxy
25 succinimide ester and polyethylene glycol-propionic acid-N-hydroxy succinimide ester.

Thus, the invention first builds the desired linked nucleoside sequence in the normal manner on the DNA synthesizer. One or more (preferably two or more) of the
30 linked nucleosides are then functionalized or derivatized with the lipophilic steroid, reporter molecule, lipophilic molecule, reporter enzyme, peptide or protein.

The following Examples illustrate the invention and are not intended to limit the same. Those skilled in the art
35 will recognize, or be able to ascertain through routine experimentation, numerous equivalents to the specific substances and procedures described herein. Such equivalents

are considered to be within the scope of the present invention. For example, those skilled in the art will appreciate that it is also possible to synthesize modified oligonucleotides appropriate for use in the methods of the invention, such as, for example, cholesterol-conjugated oligonucleotides, by using modified amidites that have become available subsequent to the earliest priority date of the present application to prepare commercially available modified amidites and controlled-pore glass (CPG) products such as those available from Glen Research (Sterling, VA; see, for example, Agrawal, Chapter 3 In: *Methods in Molecular Biology, Vol. 26: Protocols for Oligonucleotide Conjugates*, Agrawal, ed., Humana Press Inc., Totowa, NJ (1994) pages 93-120.

15

EXAMPLES

EXAMPLE 1: PREPARATION OF OLIGONUCLEOTIDES A HAVING 2'-PROTECTED-AMINE TERMINATING LINKING GROUP

A. Preparation of 5'-Dimethoxytrityl-2'-(O-Pentyl-N-phthalimido)-2'-Deoxyadenosine Phosphoramidite.

To introduce a functionalization at the 2' position of nucleotides within desired oligonucleotide sequences, 5'-dimethoxytrityl-2'-(O-pentyl-N-phthalimido)-2'-deoxyadenosine phosphoramidite was utilized to provide a linking group attached to the 2' position of nucleotide components of an oligonucleotide. This compound was synthesized generally in accordance with the procedures of parent application serial numbers US91/00243 and 07/463,358 starting from adenosine. Briefly, this procedure treats adenosine with NaH in dimethylformamide (DMF) followed by treatment with N-(5-bromopentyl)phthalimide. Further treatment with $(\text{CH}_3)_3\text{SiCl}$, Ph-C(O)-Cl and NH_4OH yields N6-benzyl protected 2'-pentyl-N-phthalimido functionalized adenosine. Treatment with DIPA and CH_2Cl_2 adds a DMT blocking group at the 5' position. Finally phosphitylation gives the desired phosphoramidite

compound. This compound was utilized in the DNA synthesizer as a 0.09M solution in anhydrous CH₃CN. Oligonucleotide synthesis was carried out in either an ABI 390B or an ABI 394 synthesizer employing the standard synthesis cycles with an extended coupling time of 10 minutes during coupling of Compound 2 into the oligonucleotide sequence. Coupling efficiency of greater than 98% was observed.

B. 2'-Protected-Amine Linking Group Containing Phosphodiester Oligonucleotides

The following oligonucleotides having phosphodiester inter-nucleotide linkages were synthesized (throughout the disclosure, unless otherwise indicated, all oligonucleotide sequences are listed in a standard 5' to 3' order from left to right):

- Oligomer 9: 5'-TA^{*}G-3';
Oligomer 10: 5'-CCA^{*}G-3';
Oligomer 11: 5'-GGC-TGA^{*}-CTG-CG-3' (SEQ ID NO:1);
Oligomer 12: 5'-CTG-TCT-CCA^{*}-TCC-TCT-TCA-CT (SEQ ID NO:2);
Oligomer 13: 5'-CTG-TCT-CCA^{*}-TCC-TCT-TCA^{*}-CT (SEQ ID NO:2),

wherein A^{*} represents a nucleotide functionalized to incorporate a pentyl-N-phthalimido functionality. Oligomers 12 and 13 are antisense compounds to the E2 region of the bovine papilloma virus-1 (BPV-1). Oligomers 12 and 13 have the same sequence as Oligomer 3 in parent application serial No. 07/782,374, except for the 2' modification. The oligonucleotides were synthesized in either a 10 μmol scale or a 3 x 1 μmol scale in the "Trityl-On" mode. Standard deprotection conditions (30% NH₄OH, 55°C, 24 hours) were employed. The oligonucleotides were purified by reverse phase HPLC (Waters Delta-Pak C₄, 15 μm, 300A, 25x100 mm column equipped with a guard column of the same material). They were detritylated and further purified by size exclusion using a Sephadex G-25 column. NMR analyses by both proton and phosphorus NMR confirmed the expected structure for the Oligomers 9 and 10.

C. 2'-Protected-Amine Linking Group Containing
Phosphorothioate Oligonucleotides

The following oligonucleotides having phosphorothioate inter-nucleotide linkages were synthesized:

- 5 Oligomer 14: $T_sT_sG_s-C_sT_sT_s-C_sC_sA^*_s-T_sC_sT_s-T_sC_sC_s-T_sC_sG_s-T_sC$
(SEQ ID NO:3);
- Oligomer 15: $T_sG_sG_s-G_sA_sG_s-C_sC_sA_s-T_sA_sG_s-C_sG_sA^*_s-G_sG_sC$
(SEQ ID NO:4); and
- Oligomer 16: $T_sG_sG_s-G_sA^*_sG_s-C_sC_sA^*_s-T_sA^*_sG_s-C_sG_sA^*_s-G_sG_sC$
10 (SEQ ID NO:4),

wherein A* represents a nucleotide functionalized to incorporate a pentyl-N-phthalimido functionality and the subscript "s" represents a phosphorothioate inter-nucleotide backbone linkage. Oligomer 14 is an antisense compound
15 directed to the E2 region of the bovine papilloma virus-1 (BPV-1). Oligomers 15 and 16 are antisense compounds to ICAM. Oligomer 14 has the same sequence as Oligomer 3 in parent application serial No. 07/782,374, except for the 2' modification whereas Oligomers 15 and 16 have the same
20 sequence as Oligomer 4 in parent application serial No. 07/782,374 except for the 2' modification. These oligonucleotides were synthesized as per the method of Example 1(B) except during the synthesis, for oxidation of the phosphite moieties, the Beaucage reagent (*i.e.*, 3H-1,2-
25 benzodithioate-3-one 1,1-dioxide; Radhakrishnan et al., *J. Am. Chem. Soc.*, 1990, 112, 1253) was used as a 0.24 M solution in anhydrous CH₃CN solvent. The oligonucleotides were synthesized in the "Trityl-On" mode and purified by reverse phase HPLC utilizing the purification procedure of
30 Example 1(B).

D. 2'-O-Methyl Derivatized, 2'-Protected-Amine
Linking Group Containing RNA Oligonucleotides

The following oligonucleotides having 2'-O-methyl groups on each nucleotide not functionalized with a 2'-
35 protected amine functionalization were synthesized:

Oligomer 17: 5'-CCA-A*GC-CUC-AGA (SEQ ID NO:24); and
Oligomer 18: 5'-CCA-GGC-UCA-GA*T (SEQ ID NO:25),

wherein A* represents a nucleotide functionalized to incorporate a pentyl-N-phthalimido functionality and where
5 the remaining nucleotides except the 3'-terminus nucleotide are each 2'-O-methyl derivatized nucleotides. The 3'-terminus nucleotide in both Oligomers 17 and 18 is a 2'-deoxy nucleotide. Both Oligomers 17 and 18 are antisense compounds to the HIV-1 TAR region. The oligonucleotides were
10 synthesized as per the method of Example 6 in parent application serial No. 07/782,374 (utilizing Compound 2 thereof) for introduction of the nucleotides containing the pentyl-N-phthalimido functionality and appropriate 2-O-methyl phosphoramidite nucleotides from Chemgenes Inc. (Needham, MA)
15 for the remaining RNA nucleotides. The 3'-terminus terminal 2'-deoxy nucleotides were standard phosphoamidites utilized for the DNA synthesizer. The oligonucleotides were deprotected and purified as per the method of Example 1(B).

20 **EXAMPLE 2: FUNCTIONALIZATION OF OLIGONUCLEOTIDES AT THE 2' POSITION**

A. Functionalization with Biotin

1. Single Site Modification

About 10 O.D. units (A_{260}) of Oligomer 12 (approximately 60 nmols based on the calculated extinction coefficient of
25 1.6756×10^5) was dried in a microfuge tube. The oligonucleotide was dissolved in 200 μ l of 0.2 M NaHCO_3 buffer and D-biotin-N-hydroxysuccinimide ester (2.5 mg, 7.3 μ mols) (Sigma, St. Louis, MO) was added followed by 40 μ l DMF. The solution was let stand overnight. The solution was
30 applied to a Sephadex G-25 column (0.7 x 15 cm) and the oligonucleotide fractions were combined. Analytical HPLC showed nearly 85% conversion to the product. The product was purified by HPLC (Waters 600E with 991 detector, Hamilton PRP-1 column 0.7 x 15 cm; solvent A: 50 mM TEAA pH 7.0; B: 45

mM TEAA with 80% acetonitrile: 1.5 ml flow rate: Gradient: 5% B for first 5 minutes, linear (1%) increase in B every minute thereafter) and further desalted on Sephadex G-25 to give the oligonucleotide:

5

Oligomer 19: 5'-CTG-TCT-CCA'-TCC-TCT-TCA-CT (SEQ ID NO:2),

wherein A' represents a nucleotide functionalized to incorporate a biotin functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the designated
10 nucleotide. HPLC retention times are shown in Table 1 below.

2. Multiple Site Modification

About 10 O.D. units (A_{260}) of Oligomer 13 (approximately 60 nmols) was treated utilizing the method of Example 8(A) (1) in parent application serial No. 07/782,374 with D-biotin-N-
15 hydroxysuccinimide ester (5 mg) in 300 μ l of 0.2 M NaHCO_3 buffer/ 50 μ l DMF. Analytical HPLC showed 65% of double labeled oligonucleotide product and 30% of single labeled products (from the two available reactive sites). HPLC and Sephadex G-25 purification gave the oligonucleotide:

20 Oligomer 20: 5'-CTG-TCT-CCA'-TCC-TCT-TCA'-CT (SEQ ID NO:2),

wherein A' represents nucleotides functionalized to incorporate a biotin functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the designated nucleotide. HPLC retention times for this product (and its
25 accompanying singly labeled products) are shown in Table 1 below. B. Functionalization with Fluorescein

1. Single Site Modification

A 1M Na_2CO_3 /1M NaHCO_3 buffer (pH 9.0) was prepared by adding 1M NaHCO_3 to 1 M Na_2CO_3 . A 200 μ l portion of this
30 buffer was added to 10 O.D. units of Oligomer 12 in a microfuge tube. A 10 mg portion of fluorescein-isocyanate in 500 μ l DMF was added to give a 0.05 M solution. A 100 μ l portion of the fluorescein solution was added to the oligonucleotide solution in the microfuge tube. The tube was

covered with aluminum foil and let stand overnight. The reaction mixture was applied to a Sephadex G-25 column (0.7 x 20 cm) that had been equilibrated with 25% (v/v) ethyl alcohol in water. The column was eluted with the same solvent. Product migration could be seen as a yellow band well separated from dark yellow band of the excess fluorescein reagent. The fractions showing absorption at 260 nm and 485 nm were combined and purified by HPLC as per the purification procedure of Example 2(A)(1). Analytical HPLC indicated 81% of the desired doubly functionalized oligonucleotide. The product was lyophilized and desalted on Sephadex to give the oligonucleotide:

Oligomer 21: 5'-CTG-TCT-CCA*-TCC-TCT-TCA-CT (SEQ ID NO:2),

wherein A* represents a nucleotide functionalized to incorporate a fluorescein functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the designated nucleotide. HPLC retention times are shown in Table 1 below.

2. Multiple Site Modification

A 10 O.D. unit (A_{260}) portion of Oligomer 13 (from Example 1) was dissolved in 300 μ l of the 1M Na_2HCO_3 / 1M Na_2CO_3 buffer of Example 2(B)(1) and 200 μ l of the fluorescein-isothiocyanate stock solution of Example 2(B)(1) was added. The resulting solution was treated as per Example 2(B)(1). Analytical HPLC indicated 61% of doubly labeled product and 38% of singly labeled products. Work up of the reaction gave the oligonucleotide:

Oligomer 22: 5'-CTG-TCT-CCA*-TCC-TCT-TCA*-CT (SEQ ID NO:2),

wherein A* represents nucleotides functionalized to incorporate a fluorescein functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the designated nucleotide. HPLC retention times are shown in Table 1 below.

C. Functionalization with Cholic Acid

1. Single Site Modification

A 10 O.D. unit (A_{260}) portion of Oligomer 12 was treated with cholic acid-NHS ester (Compound 1 in parent application
5 serial No. 07/782,374, 5 mg, 9.9 μ moles) in 200 μ l of 0.2 M NaHCO_3 buffer/ 40 μ l DMF. The reaction mixture was heated for 16 hours at 45°C. The product was isolated as per the method of Example 2(B)(1). Analytical HPLC indicated greater than 85% product formation. Work up of the reaction gave the
10 oligonucleotide:

Oligomer 23: 5'-CTG-TCT-CCA*-TCC-TCT-TCA-CT (SEQ ID NO:2),

wherein A* represents a nucleotide functionalized to incorporate a cholic acid functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the
15 designated nucleotide. HPLC retention times are shown in Table 1 below.

2. Multiple Site Modification

A 10 O.D. unit (A_{260}) portion of Oligomer 13 (see, Example 1) was treated with cholic acid-NHS ester (Compound 1
20 in Application **serial** Number 782,374, 10 mg, 19.8 μ moles) in 300 μ l of 0.2 M NaHCO_3 buffer/ 50 μ l DMF. The reaction mixture was heated for 16 hours at 45°C. The product was isolated as per the method of Example 2(A)(1). Analytical HPLC revealed 58% doubly labeled product, 17% of a first
25 singly labeled product and 24% of a second singly labeled product. Work up as per Example 2(A)(1) gave the oligonucleotide:

Oligomer 24: 5'-CTG-TCT-CCA*-TCC-TCT-TCA*-CT (SEQ ID NO:2),

wherein A* represents nucleotides functionalized to
30 incorporate a cholic acid functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the designated nucleotide. HPLC retention times are shown in Table 1 below.

D. Functionalization with Digoxigenin

1. Single Site Modification

A 10 O.D. unit (A_{260}) portion of Oligomer 12 (see, Example 1) was treated with digoxigenin-3-O-methylcarbonyl- ϵ -aminocaproic N-hydroxy succinimide ester (Boehringer Mannheim Corporation, Indianapolis, IN) in 200 μ l of 0.1 M borate pH 8.3 buffer/ 40 μ l DMF. The reaction mixture was let stand overnight. The product was isolated as per the method of Example 2(A)(1). Work up of the reaction gave the
10 oligonucleotide:

Oligomer 25: 5'-CTG-TCT-CCA*-TCC-TCT-TCA-CT (SEQ ID NO:2),

wherein A* represents a nucleotide functionalized to incorporate a digoxigenin functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the
15 designated nucleotide. HPLC retention times are shown in Table 1 below.

2. Multiple Site Modification

A 10 O.D. units (A_{260}) portion of Oligomer 13 (see, Example 1) was treated with digoxigenin-3-O-methylcarbonyl- ϵ -aminocaproic N-hydroxy succinimide ester (Boehringer Mannheim Corporation, Indianapolis, IN) in 300 μ l of 0.1 M borate pH 8.3 buffer/50 μ l DMF. The reaction mixture was let stand overnight. The product was isolated as per the method of Example 2(A)(1). Work up as per Example 2(A)(1) gave the
25 oligonucleotide:

Oligomer 26: 5'-CTG-TCT-CCA*-TCC-TCT-TCA*-CT (SEQ ID NO:2),

wherein A* represents nucleotides functionalized to incorporate a cholic acid functionality linked via a 2'-O-pentyl-amino linking group to the 2' position of the
30 designated nucleotide. HPLC retention times are shown in Table 1 below.

TABLE 1:

HPLC RETENTION TIMES OF OLIGONUCLEOTIDES
FUNCTIONALIZED AT THE 2' POSITION

5	Oligomer	Retention Time (Minutes)	
		Mono Substitution	Multiple Substitution
10	Oligomer 12 ¹	21.78	
	Oligomer 13 ¹		22.50
	Oligomer 19 ²	23.58	
	Oligomer 20 ²		24.16 ^a 25.19 ^b
	Oligomer 21 ³	26.65	
	Oligomer 22 ³		26.99 ^a 29.33 ^b 27.55 ^a
15	Oligomer 23 ⁴	30.10	
	Oligomer 24 ⁴		30.38 ^a 37.00 ^b 32.22 ^a
	Oligomer 25 ⁵	28.06	
20	Oligomer 26 ⁵		28.14 ^a 33.32 ^b 29.24 ^a

25 Conditions: Waters 600E with 991 detector, Hamilton PRP-1 column 0.7 x 15 cm; solvent A: 50 mM TEAA pH 7.0; B: 45 mM TEAA with 80% acetonitrile: 1.5 ml flow rate: Gradient: 5% B for first 5 minutes, linear (1%) increase in B every minute thereafter;

30 ^a Mono conjugated minor product;
^b Doubly conjugated major product;
¹ Parent Oligonucleotide - no 2' functionalization;
² 2' Biotin functionalization;
³ 2' Fluorescein functionalization;
⁴ 2' Cholic Acid functionalization; and
⁵ 2' Digoxigenin functionalization.

35 EXAMPLE 3: CHARACTERIZATION OF FUNCTIONALIZED OLIGO-
NUCLEOTIDES

PROCEDURE A: Confirmation of Structure of
Functionalized Oligonucleotides
Containing a Tethered 2'-Amino Moiety

Oligonucleotides of the invention were digested with
40 snake venom phosphodiesterase and calf-intestine alkaline
phosphatase to their individual nucleosides. After

digestion, the nucleoside composition was analyzed by HPLC. The HPLC analysis established that functionalized nucleotide compounds having the tethered 2'-amino moiety thereon were correctly incorporated into the oligonucleotide.

Snake venom phosphodiesterase [Boehringer-Mannheim cat. #108260, 1 mg (1.5 units)/0.5 ml] and alkaline phosphatase from calf intestine (1 unit/microliter, Boehringer-Mannheim cat. # 713023) in Tris-HCl buffer (pH 7.2, 50 mM) were used to digest the oligonucleotides to their component nucleosides. To 0.5 O.D. units of oligonucleotide in 50 μ l buffer (nearly 40 μ M final concentration for a 20 mer) was added 5 μ l of snake venom phosphodiesterase (nearly 0.3 units/mL, final concentration) and 10 μ l of alkaline phosphatase (app. 150 units/mL, final concentration). The reaction mixture was incubated at 37°C for 3 hours. Following incubation, the reaction mixture was analyzed by HPLC using a reverse phase analytical column (app. 30 x 2.5 cm); solvent A: 50 mM TEAA pH 7; solvent B: acetonitrile; gradient 100% for 10 minutes, then 5% B for 15 minutes, then 10% B and then wash. The results of these digestion are shown in Table 2 for representative oligonucleotides.

TABLE 2:
OLIGONUCLEOTIDE ANALYSIS VIA ENZYMATIC DIGESTION

25	Oligomer	Observed Ratios**				
		Abs. max.	267 C	252 G	267 T	260 A*
	Oligomer 10		2	1		1
	Oligomer 11		3	5	2	1
30	Oligomer 12		9	1	8	1
	Oligomer 13		9	1	8	2

* Nucleoside having 2'-O-linker attached thereto; and
35 ** Corrected to whole numbers.

As is evident from comparing the results in Table 2 to the Oligomer structures (see, Example 1), the correct nucleoside ratios are observed for the component nucleotides of the test oligonucleotides.

PROCEDURE B: Determination of Melting Temperatures
(T_m's) of Cholic Acid Oligonucleotide
Conjugates

The relative ability of oligonucleotides to bind to
5 their complementary strand is compared by determining the
melting temperature of the hybridization complex of the
oligonucleotide and its complementary strand. The melting
temperature (T_m), a characteristic physical property of
double helices, denotes the temperature in degrees centigrade
10 at which 50% helical versus coil (un-hybridized) forms are
present. T_m is measured by using the UV spectrum to
determine the formation and breakdown (melting) of hybridiza-
tion. Base stacking, which occurs during hybridization, is
accompanied by a reduction in UV absorption (hypochromicity).
15 Consequently, a reduction in UV absorption indicates a higher
T_m. The higher the T_m, the greater the strength of the
binding of the strands. Non-Watson-Crick base pairing has a
strong destabilizing effect on the T_m. Consequently,
absolute fidelity of base pairing is necessary to have
20 optimal binding of an antisense oligonucleotide to its
targeted RNA.

1. Terminal End Conjugates

a. Synthesis

A series of oligonucleotides were synthesized
25 utilizing standard synthetic procedures (for un-
functionalized oligonucleotides) or the procedure of Example
3(A) in parent application serial No. 07/782,374 for
oligonucleotides having a 5'-terminus amino linker bearing
oligonucleotide or the procedure of Example 3(B) in patent
30 application serial No. 07/782,374 for 5'-terminus cholic
acid-bearing oligonucleotides. Each of the oligonucleotides
had the following 5-LO antisense sequence: 5'-TCC-AGG-TGT-
CCG-CAT-C-3' (SEQ ID NO:6). The nucleotides were synthesized
on a 1.0 μmol scale. Oligomer 32 was the parent compound
35 having normal phosphodiester inter-nucleotide linkages.
Oligomer 33 incorporated phosphorothioate inter-nucleotide

linkages in the basic oligonucleotide sequence. Oligomer 34 is an intermediate oligonucleotide having a 5'-aminolink at the 5'-terminus of the basic oligonucleotide sequence and Oligomer 35 was a similar 5'-aminolink compound incorporating 5 phosphorothioate inter-nucleotide linkages. Oligomer 36 is a 5'-terminus cholic acid conjugate of the basic phosphodiester oligonucleotide sequence while Oligomer 37 is a similar 5'-cholic acid conjugate incorporating phosphorothioate inter-nucleotide linkages. Oligomers 32 and 33 were synthesized in 10 a "Trityl-On" mode and were purified by HPLC. Oligomers 34 and 35 were synthesized as per Example 3(A) in parent application serial No. 07/782,374 without or with Beaucage reagent treatment, to yield phosphodiester or phosphorothioate inter-nucleotide linkages, respectively. Oligomers 15 36 and 37 were prepared from samples of Oligomers 34 and 35, respectively, utilizing a solution of cholic acid N-hydroxy-succinimide ester (Compound 1) 1 dissolved in DMF as per Example 3(B) in parent application serial No. 07/782,374. Oligomers 36 and 37 were purified by HPLC. The products were 20 concentrated and desalted in a Sephadex G-25 column. Gel electrophoresis analyses also confirmed a pure product with the pure conjugate moving slower than the parent oligonucleotide or 5'-amino functionalized oligonucleotide.

b. Melting Analysis

25 The test oligonucleotides (either the phosphodiester, phosphorothioate, cholic acid conjugated phosphodiester, cholic acid conjugated phosphorothioate or 5'-aminolink intermediate phosphodiester or phosphorothioate oligonucleotides of the invention or otherwise) and either 30 the complementary DNA or RNA oligonucleotides were incubated at a standard concentration of 4 μ M for each oligonucleotide in buffer (100 mM NaCl, 10 mM Na-phosphate, pH 7.0, 0.1 mM EDTA). Samples were heated to 90 degrees C and the initial absorbance taken using a Guilford Response II spectro- 35 photometer (Corning, Inc., Corning, NY). Samples were then slowly cooled to 15°C and then the change in absorbance at 260 nm was monitored during the heat denaturation procedure.

The temperature was elevated 1 degree/absorbance reading and the denaturation profile analyzed by taking the 1st derivative of the melting curve. Data was also analyzed using a two-state linear regression analysis to determine the 5 Tm's. The results of these tests are shown in Table 3 as are the HPLC retention times of certain of the test compounds.

TABLE 3:
MELTING TEMPERATURE OF THE HYBRIDIZATION COMPLEX OF THE
OLIGONUCLEOTIDE AND ITS COMPLEMENTARY STRAND

10 Oligomer No.	Tm**		HPLC Ret. Time*
	DNA	RNA	(min.)
	32	62.6	62.0
	33	55.4	54.9
15	34	ND	ND
	35	ND	ND
	36	63.4	62.4
	37	56.3	55.8
20	* HPLC conditions: Walters Delta Pak C-18 RP 2.5u column; at 0 min 100% 0.1 TEAA; at 30 min 50% TEAA and 50% Acetonitrile: Flow rate 1.0 ml/min.		
25	** Tm at 4μM each strand from fit of duplicate melting curves to 2-state model with linear sloping base line. Conditions: 100 mM NaCl, 10 mM Phosphate, 0.1 mM EDTA, pH 7.0.		
	ND = not determined		

As is evident from the data presented in Table 3, conjugation of cholic acid at the end of the oligonucleotides 30 does not affect the Tm of the oligonucleotides.

2. Strands Incorporating 2'-O-Pentylamino Linker

a. Synthesis

An oligonucleotide of the sequence GGA'-CCG-GA'A'-GGT-A'CG-A'G (Oligomer 38, SEQ ID NO:7), wherein A' represents a 35 nucleotide functionalized to incorporate a pentylamino functionality at its 2'-position, was synthesized in a one micromole scale utilizing the method of Example 1(B). The oligonucleotide was purified by reverse phase HPLC, detritylated and desalted on Sephadex G-25. PAGE gel analysis 40 showed a single band. A further oligonucleotide, Oligomer 39, having the same sequence but without any 2'-O-amino

linker was synthesis in a standard manner. A complementary DNA oligonucleotide of the sequence 5'-CCT-GGC-CTT-CCA-TGC-TC (Oligomer 40, SEQ ID NO:8) was also synthesized in a standard manner as was a complementary RNA oligonucleotide of the sequence 5'-CCU-GGC-CUU-CCA-UGC-UC (Oligomer 41, SEQ ID NO:9).

b. Melting Analysis

Melting analysis was conducted as per the method of Procedure B(1)(b). The results are shown in Table 4.

10

TABLE 4:
MELTING TEMPERATURE OF THE HYBRIDIZATION COMPLEX OF
THE OLIGONUCLEOTIDE AND ITS COMPLEMENTARY STRAND

Oligomer No.	Tm°	
	DNA ¹	RNA ²
15		
38	54.5	58.0
39	60.6	56.9
(Δ_{38-39})	(6.1)	(1.1)
20		
*	Tm at 4 μ M each strand from fit of duplicate melting curves to 2-state model with linear sloping base line. Conditions: 100 mM NaCl, 10 mM Phosphate, 0.1 mM EDTA, pH 7.0.	
25	¹	Against DNA complementary strand, Oligomer 40.
	²	Against RNA complementary strand, Oligomer 41

As is evident from Table 4, against the RNA complementary strand the change in Tm's between the strand having 2'-amino linkers thereon and the unmodified strand is 1.1 degrees (0.22 change per modification). Against the DNA strand, the change is -6.1 degrees (-1.2 change per modification). When compared to the parent unmodified oligonucleotide the 2'-amino linker-containing strand has a stabilizing effect upon hybridization with RNA and a destabilizing effect upon hybridization with DNA.

Compounds of the invention were tested for their ability to increase cellular uptake. This was determined by judging either their ability to inhibit the expression of

bovine papilloma virus-1 (BPV-1) or an assay involving luciferase production (for HIV-1).

PROCEDURE C: Determination of Cellular Uptake Judged
By The Inhibition Of Expression of
5 Bovine Papilloma Virus-1 (bpv-1) As
Measured By an E2 Transactivation Assay

For this test, a phosphorothioate oligonucleotide analog of the sequence 5'-CTG-TCT-CCA-TCC-TCT-TCA-CT (Oligomer 42, SEQ ID NO:2) was used as the basic sequence.
10 This sequence is designed to be complementary to the translation initiation region of the E2 gene of bovine papilloma virus type 1 (BPV-1). Oligomer 42 served as the positive control and standard for the assay. Oligomer 3 (from Example 4 in parent application serial No. 07/782,374)
15 served as a second test compound. It has the same nucleobase sequence as Oligomer 42 but is a phosphorothioate oligonucleotide and, further, has a cholic acid moiety conjugated at the 3'-end of the oligonucleotide. Oligomer 2 (from Example 2 in parent application serial No. 07/782,374) served
20 as a third test compound. It is also of the same sequence and is a phosphorothioate oligonucleotide, but has a cholic acid moiety conjugated at its 5'-end. Oligomer 5 (from Example 5 in parent application serial No. 07/782,374) served as a fourth test compound. It also has the same nucleobase
25 sequence and is a phosphorothioate oligonucleotide, but has cholic acid moieties conjugated at both its 3'- and 5'-ends. Compounds five, six and seven served as negative controls for the assay. The fifth test compound was a phosphorothioate oligonucleotide with no significant sequence homology with
30 BPV-1. The sixth test compound was a further phosphorothioate oligonucleotide with no significant sequence homology with BPV-1. The seventh test compound, was a phosphorothioate oligonucleotide with cholic acid conjugated to the 3'-end but having no significant sequence homology
35 with BPV-1.

For each test I-38 cells were plated at 5×10^4 cells per cm^2 in 60 mm petri dishes. Eight hours after plating, medium was aspirated and replaced with medium containing the test oligonucleotide and incubated overnight. Following 5 incubation, medium was aspirated and replaced with fresh medium without oligonucleotide and incubated for one hour. Cells were then transfected by the CaPO_4 method with 2 μg of pE2RE-1-CAT. After a four hour incubation period cells were glycerol shocked (15% glycerol) for 1 minute followed by 10 washing 2 times with PBS. Medium was replaced with DMEM containing oligonucleotide at the original concentration. Cells were incubated for 48 hours and harvested. Cell lysates were analyzed for chloramphenicol acetyl transferase by standard procedures. Acetylated and nonacetylated ^{14}C - 15 chloramphenicol were separated by thin layer chromatography and quantitated by liquid scintillation. The results are expressed as percent acetylation.

Two lots of the positive control compound were found to acetylate at a level of 29% and 30%. The negative 20 controls, test compounds five, six and seven, were found to acetylate at 59%, 58% and 47%, respectively. The 3'-cholic acid conjugate test compound, Oligomer 3, was found to acetylate to 23%, the 5'-cholic acid conjugate test compound, Oligomer 2, was found to acetylate to 36% and the test 25 compound conjugated at both the 3'-end and the 5'-end, Oligomer 5, was found to acetylate to 27%.

The results of this test suggests that placement of a cholic acid moiety at the 3'-terminus of an oligonucleotide increase the activity. This in turn suggests that the 30 increased activity was the result of increased cellular membrane transport.

PROCEDURE D: Determination of Cellular Uptake Judged By Inhibition of pHIVluc With Cholic Acid Linked 2'-O-Methyl Substituted Oligonucleotides

For this test the absence of an oligonucleotide in a test well served as the control. All oligonucleotides were tested as 2'-O-methyl analogs. For this test an oligonucleotide of the sequence 5'-CCC-AGG-CUC-AGA (Oligomer 43, SEQ ID NO:10), where each of the nucleotides of the oligonucleotide includes a 2'-O-methyl substituent group served as the basic test compound. The second test compound, 5'-CHA-CCC-AGG-CUC-AGA (Oligomer 44, SEQ ID NO:10), wherein CHA represents cholic acid and where each of the nucleotides of the oligonucleotide includes a 2'-O-methyl substituent group, was also of the same sequence as the first test compound. This second test compound included cholic acid conjugated to its 5'-end and was prepared as per the method of Example 3 in parent application serial No. 07/782,374 utilizing 2'-O-methyl phosphoramidite intermediates as identified in Example 1(C). The third test compound, 5'-CCC-AGG-CUC-AGA-3'-CHA (Oligomer 45, SEQ ID NO:10), wherein CHA represents cholic acid and where each of the nucleotides of the oligonucleotide includes a 2'-O-methyl substituent group, was also of the same sequence as the first test compound. The third test compound included cholic acid conjugated to its 3'-end and was prepared as per the method of Example 4 in parent application serial No. 07/782,374 utilizing 2'-O-methyl phosphoramidite intermediates as identified in Example 1(C). The fourth test compound was a 2'-O-Me oligonucleotide of a second sequence, 5'-GAG-CUC-CCA-GGC (Oligomer 46, SEQ ID NO:11), where each of the nucleotides of the oligonucleotide includes a 2'-O-methyl substituent group. The fifth test compound was of sequence 5'-CHA-GAG-CUC-CCA-GGC (Oligomer 47, SEQ ID NO:11), wherein CHA represents cholic acid and where each of the nucleotides of the oligonucleotide includes a 2'-O-methyl substituent group. It was of the same sequence as the fourth test compound. This test compound included cholic acid conjugated to its 5'-end and was prepared as per the method of Example 3 in parent application serial Number 07/782,374 utilizing 2'-O-methyl phosphoramidite intermediates as identified in Example 1(C).

A sixth test compound was a randomized oligonucleotide of the sequence 5'-CAU-GCU-GCA-GCC (Oligomer 48, SEQ ID NO:12).

HeLa cells were seeded at 4×10^5 cells per well in 6-
5 well culture dishes. Test oligonucleotides were added to
triplicate wells at 1 μ M and allowed to incubate at 37°C for
20 hours. Medium and oligonucleotide were then removed,
cells washed with PBS and the cells were CaPO_4 transfected.
Briefly, 5 μ g of pHIVluc, a plasmid expressing the luciferase
10 cDNA under the transcriptional control of the HIV LTR
constructed by ligating the KpnI/HindIII restriction
fragments of the plasmids pT3/T7luc and pHIVpap (NAR 19(12))
containing the luciferase cDNA and the HIV LTR respectively,
and 6 μ g of pcDEBtat, a plasmid expressing the HIV tat
15 protein under the control of the SV40 promoter, were added to
500 μ l of 250 mM CaCl_2 , then 500 μ l of 2x HBS was added
followed by vortexing. After 30 minutes, the CaPO_4
precipitate was divided evenly between the six wells of the
plate, which was then incubated for 4 hours. The media and
20 precipitate were then removed, the cells washed with PBS, and
fresh oligonucleotide and media were added. Incubation was
continued overnight. Luciferase activity was determined for
each well the following morning. Media was removed, then the
cells washed 2X with PBS. The cells were then lysed on the
25 plate with 200 μ l of LB (1% Trit X-100, 25 mM Glycylglycine
pH 7.8, 15 mM MgSO_4 , 4 mM EGTA, 1mM DTT). A 75 μ l aliquot
from each well was then added to a well of a 96 well plate
along with 75 μ l of assay buffer (25 mM Glycylglycine pH 7.8,
15 mM MgSO_4 , 4 mM EGTA, 15 mM KPO_4 , 1 mM DTT, 2.5 mM ATP).
30 The plate was then read in a Dynatec multiwell luminometer
that injected 75 μ l of Luciferin buffer (25 mM Glycylglycine
pH 7.8, 15 mM MgSO_4 , 4 mM EGTA, 4 mM DTT, 1 mM luciferin) into
each well, immediately reading the light emitted (light
units).
35 The random sequence compound (Oligomer 48) and the
other non-cholic acid-conjugated test compounds (Oligomers 43
and 46) had comparable activity. The 5'-conjugate of the

first sequence (Oligomer 44) also had activity comparable to the non-conjugated compounds. The 5'-conjugate of the second sequence (Oligomer 47) showed a three-fold increase in activity compared to the non-conjugated compounds and the 3'-5 conjugate of the first sequence (Oligomer 45) showed a further 3-fold increase in activity compared to Oligomer 47.

All the test cholic acid-bearing oligonucleotides showed significant inhibition of luciferase production compared to non-cholic acid-bearing oligonucleotides. This suggests that the increased activity was the result of increased cellular membrane transport of the cholic acid-bearing test oligonucleotides.

EXAMPLE 4: PREPARATION OF MODIFIED NUCLEOSIDES AND NUCLEOTIDES, AND PHOSPHORAMIDITE AND CONTROLLED PORE GLASS (CPG) DERIVATIVES THEREOF

15

A. Preparation of 5'-O-[Dimethoxytrityl]-2'-O-[hexyl-(Ω -N-phthalimido)amino]uridine and 5'-O-[dimethoxytrityl]-3'-O-[hexyl(Ω -N-phthalimidoamino)uridine.

20 2',3'-O-Dibutyl stannylene-uridine was synthesized according to the procedure of Wagner et. al. (*J. Org. Chem.*, 1974, 39, 24). This compound was dried over P_2O_5 under vacuum for 12 hours. To a solution of this compound (29 g, 42.1 mmols) in 200 ml of anhydrous DMF were added (16.8 g, 55 mmols) of 6-bromohexyl phthalimide and 4.5 g of sodium iodide and the mixture was heated at 130°C for 16 hours under argon. The reaction mixture was evaporated, co-evaporated once with toluene and the gummy tar residue was applied on a silica column (500 g). The column was washed with 2L of ethyl acetate (EtOAc) followed by eluting with 10% methanol (MeOH):90% EtOAc. The product, 2'- and 3'-isomers of O-hexyl- Ω -N-phthalimido uridine, eluted as an inseparable mixture (R_f =0.64 in 10% MeOH in EtOAc). By ^{13}C NMR, the isomeric ration was about 55% of the 2' isomer and about 45%

of the 3' isomer. The combined yield was 9.2 g (46.2%). This mixture was dried under vacuum and re-evaporated twice with pyridine. It was dissolved in 150 mL anhydrous pyridine and treated with 7.5 g of dimethoxytrityl chloride (22.13 mmols) and 500 mg of dimethylaminopyridine (DMAP). After 2 hour, thin layer chromatography (TLC; 6:4 EtOAc:Hexane) indicated complete disappearance of the starting material and a good separation between 2' and 3' isomers ($R_f=0.29$ for the 2' isomer and 0.12 for the 3' isomer). The reaction mixture was quenched by the addition of 5mL of CH_3OH and evaporated under reduced pressure. The residue was dissolved in 300mL CH_2Cl_2 , washed successively with saturated NaHCO_3 followed by saturated NaCl solution. It was dried over Mg_2SO_4 and evaporated to give 15 g of a brown foam which was purified on a silica gel (500 g) to give 6.5 g of the 2'-isomer and 3.5 g of the 3' isomer.

B. Preparation of 5'-O-Dimethoxytrityl-2'-O-[hexyl-(Ω -N-phthalimido)amino]uridine-3'-O-(2-cyanoethyl-N,N-diisopropyl)-phosphoramidite

The 5'-dimethoxytrityl-2'-[O-hexyl-(Ω -N-phthalimido)-amino]uridine (4 g, 5.2 mmole) was dissolved in 40 mL of anhydrous CH_2Cl_2 . To this solution diisopropylaminetetrazolide (0.5 g, 2.9 mmol) was added and stirred overnight. TLC (1:1 EtOAc/hexane) showed complete disappearance of starting material. The reaction mixture was transferred with CH_2Cl_2 and washed with saturated NaHCO_3 (100 mL) followed by saturated NaCl solution. The organic layer was dried over anhydrous Na_2SO_4 and evaporated to yield 6.4 g of a crude product which was purified in a silica column (200 g) using 1:1 hexane/EtOAc to give 4.6 g (4.7 mmol, 90%) of the desired phosphoramidite.

C: Preparation of 5'-O-(Dimethoxytrityl)-3'-O-[hexyl-(Ω -N-phthalimido)amino]uridine-2'-O-succinyl-aminopropyl controlled pore glass

Succinylated and capped aminopropyl controlled pore glass (CPG; 500Å pore diameter, aminopropyl CPG, 1.0 grams prepared according to Damha et. al. (Nucl. Acids Res., 1990,

18, 3813.) was added to 12 ml anhydrous pyridine in a 100 ml round-bottom flask. 1-(3-Dimethylaminopropyl)-3-ethyl-carbo-diimide (DEC; 0.38 grams, 2.0 mmol), triethylamine (TEA; 100 μ l, distilled over CaH_2), dimethylaminopyridine (DMAP; 0.012 5 grams, 0.1 mmol) and nucleoside 5'-O-dimethoxytrityl-3'-O-[hexyl-(Ω -N-phthalimidoamino)]uridine (0.6 grams, 0.77 mmol) were added under argon and the mixture shaken mechanically for 2 hours. More nucleoside (0.20 grams) was added and the mixture shaken an additional 24 hours. CPG was filtered off 10 and washed successively with dichloromethane, triethylamine, and dichloromethane. The CPG was then dried under vacuum, suspended in 10 ml piperidine and shaken 15 minutes. The CPG was filtered off, washed thoroughly with dichloromethane and again dried under vacuum. The extent of loading (determined 15 by spectrophotometric assay of dimethoxytrityl cation in 0.3 M p-toluenesulfonic acid at 498 nm) was approximately 28 μ mol/g. The 5'-O-(dimethoxytrityl)-3'-O-[hexyl-(Ω -N-phthalimidoamino)]uridine-2'-O-succinyl-aminopropyl controlled pore glass was used to synthesize the oligomers 5'-GACU*-3' and 20 5'-GCC-TTT-CGC-GAC-CCA-ACA-CU*-3' (SEQ ID NO:13, where the * indicates the derivatized nucleotide) in an ABI 380B DNA synthesizer using phosphoramidite chemistry standard conditions. 45 and 200 O.D.'s of the 4-mer and 20-mer, respectively, were obtained from two and three 1 μ mol 25 syntheses after purification by RP-HPLC and desalting.

The oligomer 5'-GACU*-3' was used to confirm the structure of 3'-O-hexylamine tether introduced into the oligonucleotide by NMR. As expected a multiplet signal was observed between 1.0-1.8 ppm in ^1H NMR. The oligomer 5'-GCC- 30 TTT-CGC-GAC-CCA-ACA-CU*-3' (SEQ ID NO:13) belongs to a HCV sequence and it was used to show the nuclease resistance properties of the 3'-O-amino tether (see, Example 5).

D. Preparation of 5'-O-(Dimethoxytrityl)-2'-O-[hexyl-(Ω -N-phthalimido)amino] 3'-O-succinyl-aminopropyl controlled pore glass 35

The procedure of Example 4(C) was repeated, except that 5'-O-(Dimethoxytrityl)-2'-O-[hexyl-(Ω -N-

phthalimidoamido)amino]uridine was used in the loading process.

E. Preparation of 5'-O-(Dimethoxytrityl)-2'-O-(hexylamino)-uridine

5 5'-O-(dimethoxytrityl)-2'-O-[hexyl-(Ω -N-phthalimido amino)]uridine (4.5 grams, 5.8 mmol) was dissolved in 200 ml methanol in a 500 ml flask. Hydrazine (1 ml, 31 mmol) was added to the stirring reaction mixture. The mixture was heated to 60-65°C in an oil bath and refluxed 14 hours.
10 Solvent was evaporated in vacuo. The residue was dissolved in dichloromethane (250 ml) and extracted twice with an equal volume NH_4OH . The organic layer was evaporated to yield 4.36 grams of crude product, and NMR indicated that the product was not completely pure. $R_f=0$ in 100% ethyl acetate. The
15 product was used in subsequent reactions without further purification.

F. Preparation of 5'-O-(dimethoxytrityl)-3'-O-[hexylamino] uridine

The procedure of Example 4(E) was repeated, except
20 that 5'-O-(dimethoxytrityl)-3'-O-[hexyl-(Ω -N-phthalimido-amino)] uridine was used as the starting material.

G. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(1-pyrene propyl carbonyl)amino]uridine

5'-O-Dimethoxytrityl-2'-O-(hexylamino)uridine (0.5g,
25 0.78 mmol) was dissolved in anhydrous DMF (15 mL). 1-Hydroxybenzotriazole (0.16 grams, 1.17 mmol) and 1-pyrene-butyrlic acid pentafluorophenyl ester (0.53 grams, 1.17 mmol) were added to the reaction mixture. The mixture was stirred under argon at room temperature for 2 hours, after which it
30 was concentrated in vacuo. Residual DMF was coevaporated with toluene. The residue was dissolved in dichloromethane (50 mL) and washed with an equal volume saturated NaHCO_3 . The aqueous layer was washed with dichloromethane and the combined organic extracts washed with an equal volume
35 saturated NaCl . The aqueous layer was washed with dichloromethane and the combined organic layers dried over MgSO_4 and concentrated. The residue was chromatographed on a

silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 100% ethyl acetate. The desired product (0.83 grams, 58%) eluted with 100% ethyl acetate (R_f 0.46 by thin-layer chromatography (TLC)).

5 H. Preparation of 5'-O-[Dimethoxytrityl]-2'-O-[hexyl-N-(1-pyrene propyl carbonyl)amino]uridine-3'-O-(2-cyanoethyl-N, N-diisopropyl)phosphoramidite

5'-O-[Dimethoxytrityl]-2'-O-[hexyl-N-(1-pyrene propyl
10 carbonyl)amino] uridine (0.80 grams, 0.87 mmol) was dissolved in 20 mL dry dichloromethane. 2-Cyanoethyl N,N,N',N'-tetra-isopropylphosphorodiamidite (purchased from Sigma Chemical Co; 800 μ L, 2.4 mmol) and diisopropylamine tetrazolide (0.090 grams, 0.52 mmol) were added to the mixture, which was
15 stirred under argon for 20 hours. The reaction mixture was then concentrated in vacuo and the residue dissolved in dichloromethane (75 mL). The solution was washed with an equal volume of saturated NaHCO_3 . The aqueous layer was washed with dichloromethane (20 mL) and the combined organic
20 layers washed with an equal volume of saturated NaCl . The aqueous layer was washed with dichloromethane (20 mL) and the combined organic layers dried over MgSO_4 and concentrated. The residue was chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to
25 100% ethyl acetate. The desired product (750 mg, 78% yield, R_f 0.54 by TLC in 100% ethyl acetate) eluted with 100% ethyl acetate.

I. Preparation of 2'-O-[hexyl-N-(1-pyrene-propyl-carbonyl) amino] uridine

30 5'-O-dimethoxytrityl-2'-O-[hexyl-N-(1-pyrene-propyl-carbonyl)amino]uridine (1.0 g) was dissolved in 20 mL CH_2Cl_2 and kept in ice-bath for 10 minutes. To the cold solution, 5 mL of 80% acetic acid in water was added and the solution was left to stand for 30 minutes. It was then evaporated to
35 dryness and loaded into a silica column and eluted with 10% methanol in methylene chloride to give 2'-O-[hexyl-N-(1-pyrene-propyl-carbonyl)amino]uridine.

J. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(1-pyrene propyl carbonyl)amino]uridine-3'-O-[succinylaminopropyl]-controlled pore glass

Succinylated/capped aminopropyl controlled pore glass 5 was dried under vacuum for 3 hours immediately before use. A portion (0.3 g) was added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, 0.63 mmol), TEA (25 μ l, distilled over CaH_2), DMAP (0.005 grams, mmol) and 5'-O-(dimethoxytrityl)-3'-O-[hexyl-N-(1-pyrene propyl carbonyl)] amino]uridine (0.21 grams, 0.22 mmol) were added under argon and the mixture shaken mechanically for 19 hours. More nucleoside (0.025 grams) was added and the mixture shaken an additional 5.5 hours. Pentachlorophenol (0.045 grams, mmol) was added and the mixture shaken 18 hours. CPG was filtered off and washed successively with dichloromethane, triethylamine, and dichloromethane. The resulting CPG was then dried under vacuum, suspended in 15 ml piperidine and shaken 30 minutes. CPG was filtered off, washed thoroughly with dichloromethane and again dried under vacuum. The extent of loading (determined by spectrophotometric assay of dimethoxytrityl cation in 0.3 M p-toluenesulfonic acid at 498 nm) was approximately 27 μ mol/g. The product solid support was subsequently used to synthesize the oligomers.

K. Preparation of 5'-O-dimethoxytrityl-3'-O-[hexyl-N-(1-pyrene propyl carbonyl) amino] uridine-2'-O-(succinyl amino propyl) controlled pore glass

The procedure of Example 4(J) is repeated, except that 5'-O-dimethoxytrityl-3'-O-[hexyl-N-(1-pyrene propyl carbonyl)] amino] uridine is used.

L. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(5-thio carbonyl-3,6-dipivoly]-fluorescein)amino]uridine

Fluorescein isothiocyanate (Isomer I, available from Cal Biochem, La Jolla, CA) was treated with 12 equivalents of pivoly chloride in Et_3N /THF to give di-O-pivoly fluorescein isothiocyanate. This compound was purified in silica gel column using 3:1 hexane:ethyl acetate. Nucleoside 5'-O-

(dimethoxytrityl)-2'-O-(hexylamino)uridine was then condensed with dipivolyfl fluorescein isothiocyanate in CH_2Cl_2 /pyrimidine. The resultant compound 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-dipivolyfl-fluorescein)amino]uridine is then purified by using 100% ethyl acetate, in a silica column.

M. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-di-pivolyfl fluorescein) amino] uridine-3'-O-(2-cyanoethyl, N-N-diisopropyl phosphoramidite

5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-dipivolyfl fluorescein)amino]uridine (0.75 grams, 0.672 mmol) was dissolved in dry dichloromethane (20 mL). 2-Cyanoethyl N,N,N',N'-tetraisopropylphosphorodiamidite (700 μL , 2.2 mmol) and diisopropylamine tetrazolide were added to the mixture, which was stirred under argon for 16 hours. The reaction mixture was then concentrated in vacuo and the residue dissolved in dichloromethane (75 mL) followed by washing with an equal volume of saturated NaHCO_3 . The aqueous layer was washed with dichloromethane (50 mL) and the combined organic layers washed with an equal volume of saturated NaCl . The aqueous layer was washed with dichloromethane (50 mL) and the combined organic layers dried over MgSO_4 and concentrated. The residue was chromatographed on a silica gel column, eluting with a gradient of 25% ethyl acetate in hexanes to 100% ethyl acetate. The desired product (670 mg, 77% yield, R_f 0.79 by TLC) eluted with 100% ethyl acetate.

N. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-di-pivolyfl fluorescein) amino]uridine-3'-O-(succinylaminopropyl) controlled pore glass

Succinylated and capped aminopropyl controlled pore glass (CPG) is dried under vacuum for 3 hours immediately before use. CPG (0.3 grams) is added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, 0.63 mmol), TEA (25 μL , distilled over CaH_2 , DMAP (dimethyl

amino pyridine) (0.005 grams, 0.04 mmol) and 5'-O-dimethoxytrityl-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-di-pivoly fluorescein) amino] uridine (0.21 grams, 0.19 mmol) are added under argon and the mixture shaken mechanically for 19 hours. 5 More nucleoside (0.025 grams) is added and the mixture shaken an additional 5.5 hours. Pentachlorophenol (0.045 grams, 0.17 mmol) is added and the mixture shaken 18 hours. CPG is filtered off and washed successively with dichloromethane, triethylamine, and dichloromethane. CPG then is dried under 10 vacuum, suspended in 15 mL piperidine and shaken 30 minutes. CPG is filtered off, washed thoroughly with dichloromethane, and again dried under vacuum. The extent of loading is then determined by spectrophotometric assay of dimethoxytrityl cation in 0.3 M p-toluenesulfonic acid at 498 nm.

15 O. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(3-oxycarbonyl-cholesteryl)amino]uridine
 Nucleoside 5'-O-(dimethoxytrityl)-2'-O-[hexylamino]-
 uridine (3.85 g, 6.0 mmol) was dissolved in anhydrous
 pyridine/dichloromethane 50/50 (v/v) (20 mL). Cholesteryl
20 chloroformate (Fluka, 3.0 g, 6.68 mmol) was dissolved in
 anhydrous dichloromethane (20 ml) and added slowly under
 argon with a syringe to the stirring reaction mixture. The
 mixture was stirred under argon at room temperature for 2 h
 after which it was concentrated in vacuo. Residual DMF was
25 coevaporated with toluene. The residue was dissolved in
 dichloromethane (50 mL) and washed with an equal volume
 saturated NaHCO₃. The aqueous layer was washed with
 dichloromethane and the combined organic extracts washed with
 an equal volume saturated NaCl. The aqueous layer was washed
30 with dichloromethane and the combined organic layers dried
 over MgSO₄ and concentrated. The residue was chromatographed
 on a silica gel column with a gradient of 25% ethyl acetate
 in hexanes to 100% ethyl acetate. The desired product (3.78
 g, 60%) eluted with 100% ethyl acetate (R_f 0.41 by TLC).

35 P. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(3-oxycarbonyl-

cholesteryl)amino]uridine-3'-O-[2-cyanoethyl-N,N-diisopropyl]phosphoramidite

Nucleoside 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(3-oxycarbonyl-cholesteryl)amino]uridine (3.44 g, 3.3 mmol) was dissolved in dry dichloromethane (75 mL). 2-cyanoethyl N,N,N'-tetraisopropylphosphorodiamidite (Sigma, 2.1 ml, 6.6 mmol) and diisopropylamine tetrazolide (0.29 g, 1.7 mmol) were added to the mixture, which was stirred under argon for 16 H. Dichloromethane (75 mL) was added to the solution, which was washed with an equal volume of saturated NaHCO₃. The aqueous layer was washed with an equal volume of dichloromethane. The aqueous layer was washed with dichloromethane (30 ml) and the combined organic layers washed with an equal volume of saturated NaCl. The aqueous layer was washed with dichloromethane (30 mL) and the combined organic layers dried over Mg₂SO₄ and concentrated in vacuo. The residue was chromatographed on a silica gel column with a gradient of 25% ethyl acetate in hexanes to 70% ethyl acetate. The desired product (3.35 g, 82% yield, R_f=0.71 by TLC in 50% ethyl acetate in hexanes) eluted with 50% ethyl acetate.

Q. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(3-oxycarbonyl-cholesteryl)amino]uridine-3'-O-(succinylaminopropyl)-controlled pore glass

Succinylated and capped controlled pore glass (0.3 grams) is added to 2.5 ml anhydrous pyridine in a 15 ml pear-shaped flask. DEC (0.07 grams, 0.36 mmol), TEA (100 μl, distilled over CaH₂), DMAP (0.002 grams, 0.016 mmol) and 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(3-oxycarbonyl-cholesteryl)amino]uridine (0.25 grams, 0.23 mmol) are added under argon and the mixture shaken mechanically for 16 hours. More nucleoside (0.20 grams) is added and the mixture shaken an additional 18 hours. Pentachlorophenol (0.03 grams, 0.11 mmol) is added and the mixture shaken 9 hours. CPG is filtered off and washed successively with dichloromethane, triethylamine, and dichloromethane. CPG is then dried under

vacuum, suspended in 10 ml piperidine and shaken 15 minutes. CPG is filtered off, washed thoroughly with dichloromethane and again dried under vacuum. The extent of loading is determined by spectrophotometric assay of dimethoxytrityl cation in 0.3 M p-toluenesulfonic acid at 498 nm as approximately 39 $\mu\text{mol/g}$.

R. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine

5'-O-(dimethoxytrityl)-2'-O-(hexylamino)uridine (0.88 grams, 1.37 mmol) was dissolved in methanol (20 mL). 2,4-Dinitrofluorobenzene (DNFB, 0.25 grams, 1.37 mmol) was added and the mixture shaken on a mechanical shaker. The reaction was monitored by TLC. After 90 minutes, another 0.25 grams of DNFB was added and the reaction mixture shaken an additional 30 minutes, followed by addition of another 0.25 grams of DNFB. After shaking 2.5 hours, the mixture was concentrated in vacuo and chromatographed on a silica gel column, eluting with a gradient of 25% ethyl acetate in hexanes to 100% ethyl acetate. The desired product (0.51 grams, 46%) eluted with 100% ethyl acetate (R_f 0.85 by TLC).

S. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine-3'-O-(2-cyanoethyl-N,N-diisopropyl)phosphoramidite

5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine (0.45 grams, 0.55 mmol) was dissolved in dry dichloromethane (12 mL). 2-Cyanoethyl N,N,N',N'-tetraisopropylphosphorodiamidite (380 μL , 1.2 mmol) and diisopropylamine tetrazolide (0.041 grams, 0.024 mmol) were added to the mixture, which was stirred under argon for 16 hours. The reaction mixture was then concentrated in vacuo and the residue dissolved in dichloromethane (75 mL) followed by washing with an equal volume of saturated NaHCO_3 . The aqueous layer was washed with dichloromethane (25 mL) and the combined organic layers washed with an equal volume of saturated NaCl . The aqueous layer was washed with dichloromethane (25 mL) and the combined organic layers dried over MgSO_4 and concentrated. The residue was chromatographed

on a silica gel column, eluting with a gradient of 20% ethyl acetate in hexanes to 100% ethyl acetate. The desired product (510 mg foam, 93% yield, R_f 0.70 by TLC) eluted with 100% ethyl acetate. ^{31}P NMR (CDCl_3): 150.56 and 150.82 ppm.

5 T. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine-3'-O-(succinyl aminopropyl) controlled pore glass

Succinylated and capped controlled pore glass (0.3 grams) is added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, mmol), TEA (25 μl , distilled over CaH_2), DMAP (0.005 grams, 0.041 mmol) and 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine (0.21 grams, 0.26 mmol) are added under argon and the mixture shaken mechanically for 19 hours. More nucleoside (0.025 grams) is added and the mixture shaken an additional 5.5 hours. Pentachlorophenol (0.045 grams, 0.16 mmol) is added and the mixture shaken 18 hours. CPG is filtered off and washed successively with dichloromethane, triethylamine, and dichloromethane. CPG then is dried under vacuum, suspended in 15 ml piperidine and shaken for 15 minutes. CPG is filtered off, washed thoroughly with dichloromethane, and again dried under vacuum. The extent of loading is determined by spectrophotometric assay of dimethoxytrityl cation in 0.3 M p-toluenesulfonic acid at 498 nm, as approximately 29 $\mu\text{mol/gm}$.

 U. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(N α -Nimid-Di-FMOC-L-Histidyl)amino]uridine

Nucleoside 5'-O-(dimethoxytrityl)-2'-O-(hexylamino)-uridine (0.97 g, 1.51 mmol) was dissolved in dichloromethane (25 mL) and cooled to 0°C in an ice bath. N α ,Nimid-Di-FMOC-L-histidine pentafluorophenyl ester (2.4 g, 3.1 mmol, purchased from Sigma) and 1-hydroxybenzotriazole (0.32 g, 0.24 mmol, purchased from Fluka) were added to the stirred reaction mixture stirred under argon. After 15 minutes, the ice bath was removed and the mixture stirred under argon at room temperature for 72 h. The mixture was concentrated in vacuo

and chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 70% ethyl acetate in hexanes. The desired product (0.53 g, 28%) eluted with 70% ethyl acetate (R_f 0.53 by TLC in 100% ethyl acetate).

5 V. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(N α -Nimid-Di-FMOC-L-histidyl)-amino]-uridine-3'-O-[2-cyanoethyl-N,N-diisopropyl]phosphoramidite

5'-O-Dimethoxytrityl-2'-O-[hexyl-N-(N α -Nimid-Di-FMOC-
10 L-histidyl)amino]uridine (1.9 g, 1.6 mmol) is dissolved in dry dichloromethane (20mL). 2-Cyanoethyl N,N,N',N'-tetraiso-propylphosphorodiamidite (800 μ L, 2.4 mmol) and diisopropyl-amine tetrazolide (0.090 grams, 0.52 mmol) are added to the mixture, which is stirred under argon for 20 hours. The
15 reaction mixture then is concentrated in vacuo and the residue dissolved in dichloromethane (75 mL). The solution is washed with an equal volume of saturated NaHCO₃. The aqueous layer is washed with dichloromethane (20 mL) and the combined organic layers washed with an equal volume of
20 saturated NaCl. The aqueous layer is washed with dichloromethane (20 mL) and the combined organic layers dried over MgSO₄ and concentrated. The residue is chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 100% ethyl acetate. The desired
25 product elutes with 100% ethyl acetate.

W. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(N α -Nimid-Di-FMOC)-L-histidyl)amino]uridine-3'-O-[succinylaminopropyl]
 controlled pore glass

30 Succinylated and capped controlled pore glass (dried under vacuum for 3 hours immediately before use; 0.3 grams) is added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, 0.63 mmol), TEA (25 μ l, distilled over CaH₂), DMAP (0.005 grams, 0.04 mmol) and 5'-O-(dimethoxy-
35 trityl)-2'-O-[hexyl-N-(N α -Nimid-Di-FMOC)-L-histidyl)amino]-uridine (0.21 grams, 0.17 mmol) are added under argon and the mixture shaken mechanically for 19 hours. More nucleoside

(0.025 grams) is added and the mixture shaken an additional 5.5 hours. Pentachlorophenol (0.045 grams, 0.17 mmol) is added and the mixture shaken 18 hours. CPG is filtered off and washed successively with dichloromethane, triethylamine, 5 and dichloromethane. CPG then is dried under vacuum, suspended in 15 ml piperidine and shaken 15 minutes. CPG is filtered off, washed thoroughly with dichloromethane and again dried under vacuum. The extent of loading is determined by spectrophotometric assay of dimethoxytrityl 10 cation in 0.3 M p-toluenesulfonic acid at 498 nm. to be approximately 27 $\mu\text{mol/g}$.

X. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(Ω -methyl-polyethylene glycol-propionoyl)amino]uridine

15 Nucleoside 5'-O-(dimethoxytrityl)-2'-O-[hexylamino]-uridine, (1 g, 1.55 mmol) is dissolved in anhydrous DMF (15 mL). 1-Hydroxybenzotriazole (0.24 g, 1.75 mmol) and polyethylene glycol-propionic acid-NHS-ester (1.23 g, 1.75 mmol) are added to the reaction mixture. The mixture is 20 stirred under argon at room temperature for 2 hours after which it is concentrated in vacuo. Residual DMF is coevaporated with toluene. The residue is dissolved in dichloromethane (50 mL) and then washed with an equal volume saturated NaHCO_3 . The aqueous layer is washed with 25 dichloromethane and the combined organic extracts washed with an equal volume saturated NaCl . The aqueous layer is washed with dichloromethane and the combined organic layers dried over MgSO_4 and concentrated. The residue is chromatographed on a silica gel column, eluting with a gradient of 50% ethyl 30 acetate in hexanes to 100% ethyl acetate. The desired product (1.08 g, 58%) eluted with 100% ethyl acetate.

Y. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(Ω -methyl-polyethylene glycol-propionoyl)amino]uridine-3'-O-(2-cyanoethoxy-N,N- 35 diisopropyl)phosphoramidite

5'-O-(Dimethoxytrityl)-2'-O-[hexyl-N-(Ω -methyl-polyethylene glycol-propionoyl)amino]uridine (1.04 grams,

0.87 mmol) is dissolved in dry dichloromethane (20mL). 2-Cyanoethyl *N,N,N',N'*-tetraisopropylphosphorodiamidite (800 μ L, 2.4 mmol) and diisopropylamine tetrazolide (0.090 grams, 0.52 mmol) are added to the mixture, which is stirred under 5 argon for 20 hours. The reaction mixture then is concentrated *in vacuo* and the residue dissolved in dichloromethane (75 mL). The solution is washed with an equal volume of saturated NaHCO_3 . The aqueous layer is washed with dichloromethane (20 mL) and the combined organic layers 10 washed with an equal volume of saturated NaCl . The aqueous layer is washed with dichloromethane (20 mL) and the combined organic layers dried over MgSO_4 and concentrated. The residue is chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 100% ethyl 15 acetate. The desired product elutes with 100% ethyl acetate.

Z. Preparation of 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(Ω -methyl-polyethylene glycol-propionoyl)amino]uridine-3'-O-(succinyl-aminopropyl) controlled pore glass

20 Succinylated and capped controlled pore glass (CPG) is dried under vacuum for 3 hours immediately before use. Controlled pore glass (0.3 grams) is added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, 0.67 mmol), TEA (25 μ l, distilled over CaH_2), DMAP (0.005 25 grams, mmol) and 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(ω -methyl-polyethylene glycol-propionoyl)amino]uridine (0.21 grams, 0.175 mmol) are added under argon and the mixture shaken mechanically for 19 hours. More nucleoside (0.025 grams) is added and the mixture shaken an additional 5.5 30 hours. Pentachlorophenol (0.045 grams, 0.17 mmol) is added and the mixture shaken 18 hours. CPG is filtered off and washed successively with dichloromethane, triethylamine, and dichloromethane. CPG then is dried under vacuum, suspended in 15 ml piperidine, and shaken 15 minutes. CPG is filtered 35 off, washed thoroughly with dichloromethane, and again dried under vacuum. The extent of loading is determined by spectrophotometric assay of dimethoxytrityl cation in 0.3 M

p-toluenesulfonic acid at 498 nm. to be approximately 18 $\mu\text{mol/g}$.

AA. Preparation of macrocycle derivatized nucleoside
5'-O-(dimethoxytrityl)-2'-O-(hexylamine)uridine is
5 treated as per the procedure of Example 3 with the macrocycle
4-{1,4,8,11-tetraza-[tri-(trifluoroacetyl)cyclotetradec-1-
yl]}methyl benzoic acid-N-hydroxy succinimide ester (prepared
according to Simon Jones et. al. (*Bioconjugate Chem.* 1991, 2,
416) to yield the product.

10 AB. Preparation of macrocycle derivatized uridine
phosphoramidite

The nucleoside product of Example 4(AA) is treated as
per the procedure of Example 4(B) to yield the product.

15 AC. Preparation of CPG derivatized with macrocycle
derivatized nucleoside

The nucleoside product of Example 4(AA) is treated as
per the procedure of Example 4(C) to yield the product.

AD. Preparation of 5'-O-(dimethoxyltrityl)-2'-O-
(hexyl-N-(folate)amino)uridine

20 5'-O-(Dimethoxytrityl)-2'-O-(hexylamine)uridine is
treated as per the procedure of Example 4(A) with folic acid
pentafluorophenyl ester (protected with an isobutyryl
protecting group) to yield the product.

25 AE. Preparation of 5'-O-(dimethoxyltrityl)-2'-O-
[hexyl-N-(folate)amino]uridine-3'-O-(2-
cyanoethoxy-N,N-diisopropyl)phosphoramidite

The nucleoside product of Example 4(AB) is treated as
per the procedure of Example 4(B) to yield the product.

30 AF. Preparation of CPG derivatized with 5'-O-
(dimethoxyltrityl)-2'-O-(hexyl-N-(folate)amino)-
uridine nucleoside

The nucleoside product of Example 4(AE) is treated as
per the procedure of Example 4(C) to yield the product.

AG. Preparation of 5'-O-(dimethoxytrityl)-2'-O-{hexyl-N-[2-methoxy-6-chloro-9-(Ω -amino-caproyl)acridine]amino}uridine

6,9-Dichloro-2-methoxyacridine (Adlrich, 10 g, 36 5 mmol) and phenol (2.5 g) were placed together on a round-bottom flask with a stirring bar and to this 6-amino-hexanoic acid (9.3 g, 71 mmol) was added and the flask was heated to 100°C (oil bath) for 2 hours. TLC (10% methanol in methylene chloride) showed complete disappearance of starting material. 10 The reaction mixture was cooled and poured into 200 mL of methanol. The product isolates out as a yellow solid (about 10 g). This compound was then converted into its pentafluorophenol ester.

5'-O-(Dimethoxytrityl)-2'-(hexylamino)uridine (0.5g, 15 0.78 mmol) is dissolved in anhydrous DMF (15 mL). 1-Hydroxy-benzotriazole (0.16 grams, 1.17 mmol) and 2-methoxy-6-chloro-9-(Ω -caproyl-amino) acridine pentafluorophenyl ester (0.53 grams, 1.17 mmol) are added to the reaction mixture. The mixture is stirred under argon at room temperature for 2 h, 20 after which it is concentrated in vacuo. Residual DMF is coevaporated with toluene. The residue is dissolved in dichloromethane (50 mL) and washed with an equal volume saturated NaHCO₃. The aqueous layer is washed with dichloromethane and the combined organic extracts washed with 25 an equal volume saturated NaCl. The aqueous layer is washed with dichloromethane and the combined organic layers dried over MgSO₄ and concentrated. The residue is chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 100% ethyl acetate. The desired 30 product elutes with 100% ethyl acetate.

AH. Preparation of 5'-O-(dimethoxytrityl)-2'-O-{hexyl-N-[2-methoxy-6-chloro-9-(Ω -amino-caproyl)acridine]amino}uridine-3'-O-(2-cyanoethyl-N,N-diisopropyl) phosphoramidite

35 5'-O-Dimethoxytrityl-2'-O-{hexyl-N-[2-methoxy-6-chloro-9-(ω -amino-caproyl)acridine]amino}uridine (0.80 grams, 0.77 mmol) is dissolved in dry dichloromethane (20mL). 2-

Cyanoethyl *N,N,N',N'*-tetraisopropylphosphorodiamidite (800 μ L, 2.4 mmol) and diisopropylamine tetrazolide (0.090 grams, 0.52 mmol) are added to the mixture, which is stirred under argon for 20 hours. The reaction mixture is then

5 concentrated *in vacuo* and the residue dissolved in dichloromethane (75 mL). The solution is washed with an equal volume of saturated NaHCO_3 . The aqueous layer is washed with dichloromethane (20 mL) and the combined organic layers washed with an equal volume of saturated NaCl . The aqueous

10 layer is washed with dichloromethane (20 mL) and the combined organic layers dried over MgSO_4 and concentrated. The residue is chromatographed on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 92% ethyl acetate. The desired product elutes with 100% ethyl acetate.

15 AI. Preparation of 5'-O-(dimethoxytrityl)-2'-O-{hexyl-N-[2-methoxy-6-chloro-9-(Ω -aminocaproyl)acridine]amino}uridine-3'-O-(succinyl aminopropyl) controlled pore glass

Succinylated and capped controlled pore glass (0.3

20 grams) is added to 3 ml anhydrous pyridine in a 50 ml round-bottom flask. DEC (0.12 grams, 0.67 mmol), TEA (25 μ l, distilled over CaH_2), DMAP (0.005 grams, 0.04 mmol) and 5'-O-dimethoxytrityl-2'-O-{hexyl-N-[2-methoxy-6-chloro-9-(Ω -aminocaproyl)acridine]amino}uridine (0.21 grams, 0.17 mmol)

25 are added under argon and the mixture shaken mechanically for 19 hours. More nucleoside (0.025 grams) is added and the mixture shaken an additional 5.5 hours. Pentachlorophenol (0.045 grams, 0.17 mmol) is added and the mixture shaken 18 hours. CPG is filtered off and washed successively with

30 dichloromethane, triethylamine, and dichloromethane. CPG is then dried under vacuum, suspended in 15 ml piperidine and shaken 15 minutes. CPG is filtered off, washed thoroughly with dichloromethane and again dried under vacuum. The extent of loading is determined by spectrophotometric assay

35 of dimethoxytrityl cation in 0.3 M *p*-toluenesulfonic acid at 498 nm. to be approximately 27 $\mu\text{mol/g}$.

AJ. Preparation of 5'-O-(dimethoxytrityl)-2'-O-
[(hexyl-N,N-dimethyl)amino]uridine

5'-O-(dimethoxytrityl)-2'-O-(hexylamino)uridine (0.19 grams, 0.29 mmol) is dissolved in 4 ml methanol. Sodium acetate pH 4.0 (2 ml), sodium cyanoborohydride (0.02 grams, 0.3 mmol) and 37% formaldehyde in water (300 μ l) are added to the reaction mixture, which is stirred 2 hours, after which it is concentrated *in vacuo*. The residue is dissolved in dichloromethane (50 mL) and washed with an equal volume
10 saturated NaHCO₃. The aqueous layer is washed with dichloromethane and the combined organic extracts washed with an equal volume saturated NaCl. The aqueous layer is washed with dichloromethane and the combined organic layers dried over MgSO₄ and concentrated. The residue is chromatographed
15 on a silica gel column, eluting with a gradient of 50% ethyl acetate in hexanes to 100% ethyl acetate. The desired product (0.15 grams, 80%) elutes with 10% Methanol-90% ethyl acetate.

EXAMPLE 5: OLIGONUCLEOTIDES HAVING A 3'-ALKYLAMINO GROUP

20 3'-O-Hexyl-(N-phthalimido)-aminouridine-CPG, i.e. the 5'-O-dimethoxytrityl-3'-O-[hexyl-(Ω -N-phthalimido amino)]-uridine-2'-O-(succinyl-aminopropyl) controlled pore glass from Example 4(C), was used to synthesize the following oligonucleotides:

25 Oligomer 49: 5'-GACU*

Oligomer 50: 5'-GCC-TTT-CGC-GAC-CCA-ACA-CU (SEQ ID NO:13)

Oligomer 51: 5'-GCC-TTT-CGC-GAC-CCA-ACA-CU* (SEQ ID NO:13),

wherein "*" denotes the 3'-O hexylamino-modified nucleoside. Standard commercial phosphoramidites were used with the
30 synthesis cycle times specified by the manufacturer in a 380B ABI instrument (Applied Biosystems).

Oligomer 49 was used for structural proof of 3'-O-alkylamine-bearing oligonucleotides at the 3'-terminal end.

It showed the expected three ^{31}P NMR signals (-0.5 ppm, -0.25 ppm, -0.2 ppm) and seven lines in the trace aromatic base region in ^1H NMR its spectrum.

Oligomer 51 was used to demonstrate the nuclease resistance offered by this the alkylamino group and also for further conjugation. The oligomer was treated with pyrene-butyric acid-N-hydroxy succinimide ester in 0.2 M NaHCO_3 buffer/DMF. The product, Conjugate 1, was purified by HPLC and size exclusion methods. HPLC retention times (eluting with a gradient of 5% CH_3CN for 10 minutes then 5%-40% CH_3CN for 50 minutes) were as follows: Oligomer 50, 25.99 min.; Oligomer 51, 25.91 min.; and Conjugate 1, 49.35 min.

The nuclease stability of Oligomer 51 and the conjugate were tested against Oligomer 50 in HeLa cytoplasmic/nuclear extracts. The cell extract was diluted 1.4 times. The final concentration of oligonucleotide was 20 μM . The half lives of the oligonucleotides were as follows: Oligomer 50, 1.0 hrs.; Oligomer 51, 3.5 hrs.; and Conjugate 1, 3.6 hrs.

The half life of phosphodiester Oligomer 50 increased 3-4 times by simple modification at the 3'-end with the hexylamino group by itself, an attribute that was unaffected by further conjugation.

EXAMPLE 6: 2'-O-MODIFIED OLIGONUCLEOTIDES

A. $\text{GCGTGU}^*\text{CTGCG}$ where U^* is hexyl-(Ω -N-phthalimido)amino]-uridine

The phosphoramidite from Example 4(B), 5'-O-(dimethoxytrityl)-2'-O-[hexyl-(Ω -N-phthalimido)amino]-uridine-3'-O-[(2-cyanoethyl)-N,N-diisopropyl]phosphoramidite was made as a 0.2 M solution in anhydrous CH_3CN and used to synthesize the following oligonucleotides in an ABI DNA synthesizer, model 380 B. During the modified amidite coupling, the reaction time was increased to 10 minutes. A coupling efficiency of approximately 90% was observed. After deprotection with concentrated ammonium hydroxide (55°C, 16

hours) the following oligonucleotides were purified by reverse phase HPLC and desalting column (Sephadex G-25):

Oligomer 52: 5'-GCG-TGU^{*}-CTG-CG (SEQ ID NO:14); and
5 Oligomer 53: 5'-GAU^{*}CT.

B. GCGTGTU[']CTGCG where U['] is 2'-O-[hexyl-N-(1-pyrene-propyl-carbonyl)amino uridine, Conjugate 2 (Oligomer 52 - pyrene butyrate conjugate).

To 20 O.D. of Oligomer 52 in 200 μ L of 0.2 M NaHCO₃ buffer, 5 ml of pyrene-butyric acid-N-hydroxy succinimide ester in an Eppendorf tube was added followed by 200 μ L of DMF. The tube was shaken overnight. The reaction was purified by size exclusion and HPLC to yield 18 O.D. of product.

15 C. GCGTGTU["]CTGCG where U["] is 2'-O-[6-bromoacetymido-hex-1yl]-uridine, Conjugate 3 (Oligomer 52 - bromoacetate conjugate).

To 12 O.D. of Oligomer 52 in 100 μ L of 0.2 M NaHCO₃ buffer, 2 mg bromoacetic acid-NHS ester (N-hydroxy succinimidyl bromoacetate) was added. After leaving the reaction to stand overnight, it was purified by size exclusion and HPLC to yield 7.5 O.D. of product.

25 D. GCGTGTU[^]CTGCG where U[^] is 2'-O-[hexyl-N-(polyethylene glycol)-propionoyl]amino uridine, Conjugate 4 (Oligomer 52 - PEG conjugate).

To 24 O.D. of Oligomer 52 in 200 μ L of 0.2 M NaHCO₃ buffer, 20 mg of Polyethylene glycol propionic acid-N-hydroxy succinimide ester was added. The reaction was mechanically shaken overnight and purified by Sephadex G-25 size exclusion and chromatography to yield 22 O.D. of product.

HPLC retention times (eluting with a gradient of 5% CH₃CN for 10 minutes then 5%-40% CH₃CN for 50 minutes in a C-18 Delta-Pak reverse phase column) were as follows: Oligomer 52, 24.05 min.; Conjugate 2, 40.80 min.; Conjugate 3, 26.04 min.; and Conjugate 4, 55.58 min.

Changes in T_m due to pyrene conjugation were evaluated against both DNA and RNA. T_m was measured in 100 mM Na⁺, 10 mM phosphate, 0.1 mM EDTA, pH 7 at 4 μ M strand concentration.

The results were as follows:

5

TABLE 5:
MELTING TEMPERATURE OF THE HYBRIDIZATION COMPLEX OF
THE OLIGONUCLEOTIDE AND ITS COMPLEMENTARY STRAND

	<u>T_m v. DNA ($^{\circ}$C)</u>	<u>T_m v. RNA ($^{\circ}$C)</u>
Oligomer 52	50.9	55.5
10 Conjugate 2	55.3	55.5
Δ_{052-C2}	(4.4)	(0.0)

The values in parentheses are changes in T_m compared to amino linker in oligomer 52 as a control.

15 **EXAMPLE 7: OLIGONUCLEOTIDE SYNTHESIS USING 2'-O-HEXYLAMINO-FUNCTIONALIZED URIDINE PHOSPHORAMIDITES**

A. 2'-O-hexylamino(pyrenebutyrate)uridine phosphoramidite

20 The amidite 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(1-pyrene propyl carbonyl)amino]uridine-3'-O-(2-cyanoethyl-N,N-diisopropyl) phosphoramidite (0.2M in anhydrous acetonitrile) was used to synthesize the following oligomers, both for NMR studies:

Oligomer 54: 5'-GAU^UCT, and
Oligomer 55: 5'-GCC-GU^UG-TCG,

25 where U^U is a 2'-O-modified phosphoramidite.

These oligomers were purified trityl-on reverse-phase HPLC, detritylated in 80% acetic acid for one hour and then repurified by RP-HPLC and desalted by size-exclusion chromatography. NMR analysis showed the presence of pyrene 5 peaks.

B. 2'-O-hexylamino(dinitrophenyl)uridine phosphoramidite

The amidite 5'-O-(dimethoxytrityl)-2'-O-[hexyl-N-(2,4-dinitrophenyl)amino]uridine-3'-O-(2-cyanoethyl-N,N-diisopropyl)phosphoramidite (0.18 M in anhydrous acetonitrile) was used to synthesize the oligonucleotides, Oligomers 56 to 63. All are analogues of an ICAM antisense sequence. These oligomers were purified trityl-on by RP-HPLC (Waters Delta-Pak C₁₈ column, 300 Å, 7.8 mm x 30 cm, linear 50-min gradient of 5-60% acetonitrile in 0.05 M TEAA pH 7.3), detritylated in 80% acetic acid for one hour and then purified by RP-HPLC and desalted by size-exclusion chromatography. Data are summarized below in Table 6:

TABLE 6:

HPLC RETENTION TIMES OF OLIGONUCLEOTIDES

	Backbone	Total (O.D.)	Retention Time (min.)
Oligomer 56: GAU ⁺ CT	P=O	40	39.16
25 Oligomer 57 (SEQ ID NO:15): U ⁺ GG-GAG-CCA-TAG-CGA-GGC#	P=S	64	39.19
Oligomer 58 (SEQ ID NO:15): U ⁺ GG-GAG-CCA-TAG-CGA-GGC	P=S	45	39.21
30 Oligomer 59 (SEQ ID NO:15): U ⁺ GG GAG CCA TAG CGA GGC	P=O	60	37.68
Oligomer 60 (SEQ ID NO:5): U ⁺ GG GAG CCA U ⁺ AG CGA GGC	P=O	69	38.58
35 Oligomer 61 (SEQ ID NO:16): TGG GAG CCA U ⁺ AG CGA GGC	P=O	86	32.38
Oligomer 62 (SEQ ID NO:17): U ⁺ CT GAG TAG CAG AGG AGC TC#	P=O	34	35.76

Oligomer 63 (SEQ ID NO:5): P=S 72 43.37
 U[•]GG GAG CCA U[•]AG CGA GGC#

#=Non-nucleoside 6-carbon amino linker (Glen Research) and
Bold indicates nucleotides having 2'-O-methyl substitutions

5 C. Oligonucleotide synthesis using 2'-O-[hexylamino-
 (cholesterol)]uridine phosphoramidite

The amidite 5'-O-dimethoxytrityl-2'-O-[hexyl-N-(3-oxycarbonyl-cholesteryl)amino]uridine-3'-O-[2-cyanoethyl-N,N,-diisopropyl]-phosphoramidite (0.2M in anhydrous aceto-
 10 nitrile/dichloromethane 2:1 v/v) was used to synthesize
 Oligomers 67-74. These oligomers are purified trityl-on by
 reverse-phase HPLC (Waters Delta-Pak C₁₈, 300Å, 7.8 mm x 30
 cm, linear 55-min gradient of 5-80% acetonitrile in 0.05 M
 TEAA pH 7.3), detritylated in 80% acetic acid for one hour
 15 and then repurified by RP-HPLC and desalted by size-exclusion
 chromatography. Data are summarized below in Table 7.

TABLE 7:
 HPLC RETENTION TIMES OF OLIGONUCLEOTIDES

	Backbone	Target (use)	Retention Time (min.)
20 Oligomer 67: GAU [•] CT	P=O	(NMR)	52.73
Oligomer 68 (SEQ ID NO:15): U [•] GG-GAG-CCA-TAG-CGA-GGC	P=O	ICAM	49.64
25 Oligomer 69 (SEQ ID NO:18): U [•] GC-CCA-AGC-TGG-CAT-CCG-TCA	P=S	ICAM	51.98
Oligomer 70 (SEQ ID NO:19): U [•] GC-GTT-TGC-TCT-TCT-TCT-TGC-G	P=S	CMV	52.57
Oligomer 71 (SEQ ID NO:20): 30 U [•] GC-ATC-CCC-CAG-GCC-ACC-AT	P=S	mseICAM	53.24

Oligomer 72 (SEQ ID NO:21):	P=S	Raf	53.95
U ¹ CC-CGC-CTG-TGA-CAT-GCA-TT			
Oligomer 73 (SEQ ID NO:22):	P=S	PKCα	51.04
GU ¹ T-CTC-GCT-GGT-GAG-TTT-CA			
5 Oligomer 74 (SEQ ID NO:23):	P=S	ICAM	52.75
Fl-UU ¹ GG-GAG-CCA-TAG-CGA-GGC			
(Fl-U = U 2'-modified with fluorescein; see Example 8(A))			

D. Synthesis of oligonucleotides using 2'-O-[hexylamino-(fluorescein)] amidite

10 The amidite 5'-O-dimethoxytrityl-2'-O-[hexyl-N-(5-thiocarbonyl-3,6-dipivoyl fluorescein)amino]uridine-3'-O-(cyanoethyl-N,N-diisopropyl phosphoramidite) (0.2 M in anhydrous acetonitrile) was used to synthesize Oligomer 74 (above) and Oligomers 75-82 on a 1 x 10⁵ (Oligomer 75) or 1 x 15 10² (remaining Oligomers) μmol scale. These oligomers are purified trityl-on by reverse phase HPLC (Waters Delta-Pak C₁₈, 300Å, 7.8 mm x 30 cm, linear gradient of acetonitrile in 0.05 M TEAA pH 7.3), detritylated in 80% acetic acid for one hour and then repurified by RP-HPLC and desalted by size- 20 exclusion chromatography.

TABLE 8:
STRUCTURES OF OLIGOMERS 75 TO 82

	Backbone	Target
Oligomer 75:		
25 GAU ¹ CT	P=O	(NMR)
Oligomer 76 (SEQ ID NO:15):		
U ¹ GC-GAG-CCA-TAG-CGA-GGC	P=O	ICAM
Oligomer 77 (SEQ ID NO:6):		
U ¹ GC-CCA-AGC-TGG-CAT-CCG-TCA	P=S	ICAM
30 33 Oligomer 78 (SEQ ID NO:6):		
U ¹ GC-CCA-AGC-TGG-CAT-CCG-TCA#	P=S	ICAM
Oligomer 79 (SEQ ID NO:19):		

U^{*}GC-GTT-TGC-TCT-TCT-TCT-TGC-G

P=S

CMV

Oligomer 80 (SEQ ID NO:20):

U^{*}GC-ATC-CCC-CAG-GCC-ACC-AT

P=S

mseICAM

Oligomer 81 (SEQ ID NO:20):

5 U^{*}GC-ATC-CCC-CAG-GCC-ACC-A(U-CPG)

P=S

mseICAM,

where (U-CPG)=2'-O-hexylphthalimido U 6

Oligomer 82 (SEQ ID NO:22):

GU^{*}T-CTC-GCT-GGT-GAG-TTT-CA

P=S

PKC,

where U^{*} is U modified with fluorescein.

10 EXAMPLE 8: PREPARATION OF DERIVATIZED THYMIDINE PHOSPHORAMIDITES

A. 3-Benzyloxymethyl-3'-benzyloxymethyl-5'-O-tert-butyl-diphenyl silylthymidine

To a mechanically stirred solution of 5'-O-tertbutyl-
15 diphenylsilylthymidine (170 g, 350 mmol) and diisopropylethylamine (200 g, 1547 mmol) in methylene chloride (1000 ml) was added dropwise benzyl chloromethylether (171 g, 1092 mmol). Upon completion of a mild exotherm, the reaction was heated to 40°C for 16 h.

20 Whereupon the reaction was washed with cold 5% HCl, H₂O, sat. NaHCO₃, dried (MgSO₄) and concentrated in vacuo. The resulting oil was chromatographed on silica gel (EtOAc/hexane, 8/2) to afford the product as a viscous oil, 251 g (71%). ¹H NMR(CDCl₃) 1.09 (s, 9H, (CH₃)₃), 1.60 (s, 3H, C5-CH₃), 2.05 (ddd, 1H, C2'b), 2.52 (ddd, 1H, C2'a), 3.81 (dd, 1H, C5'HH), 3.94 (dd, 1H, C5'HH), 4.08 (m, 1H, C4'H), 4.5 (m, 1H, C3'H), 4.61 (s, 2H, OCH₂Ph), 4.72 (s, 2H, OCH₂Ph), 4.80 (s, 2H, OCH₂O), 5.51 (s, 2H, NCH₂O), 6.39 (m, 1H, C1'H), 7.26-7.5 (m, 21H, CH=,ArH). Anal. Calcd. for C₄₂H₄₈N₂O₇Si: C, 69.97; 30 H, 6.71; N, 3.89. Found: C, 69.81; H, 6.42; N, 3.91.

B. 3-Benzyloxymethyl-3'-benzyloxymethylthymidine

A solution of 3-benzyloxymethyl-3'-benzyloxymethyl-5'-
O-tert-butyl-diphenylsilylthymidine (20 g, 28 mmol) in THF
(200 ml) was treated with tert-butyl ammonium fluoride 1M/THF
35 (40 ml, 40 mmol) at room temperature for 16 hrs. The solution was concentrated in vacuo and the resulting oil chromatographed on silica gel (EtOAc/hexane, 7/3→8/2) to

afford the product, 10 g (75%). m.p. 83-84°C; ¹H NMR (CDCl₃), 1.92 (s, 3H, C5-CH₃), 2.20-2.50 (m, 3H, C2'H, C5'OH), 3.73 (dd, 1H, C5'HH), 3.89 (dd, 1H, C5'HH), 4.09 (m, 1H, C4'H), 4.49 (m, 1H, C3'H), 4.62 (s, 2H, OCH₂Ph), 4.70 (s, 2H, OCH₂Ph), 4.81 (s, 2H, OCH₂O), 5.49 (s, 2H, NCH₂O), 6.19 (t, 1H, C1'H), 7.26-7.37 (m, 5H, CH=, ArH). Anal. Calcd. for C₂₆H₃₀N₂O₇: C, 64.94; H, 6.26; N, 5.75. Found: C, 64.71; H, 6.27; N, 5.81.

C. 3-Benzylloxymethyl-3'-benzylloxymethylthymidine-5'-aldehyde

10 A solution of 3-benzylloxymethyl-3'-benzylloxymethylthymidine (14.5 g, 30 mmol) in DMSO (200 ml) was treated with DCC (33 g, 160 mmol) and phosphoric acid 85% (2.0 g) for 16h. The reaction mixture was filtered and concentrated in vacuo. The resultant oil was chromatographed
15 on silica gel (EtOAc/hexane, 7/3) to afford the product as a viscous oil, 11 g (76%). ¹H NMR (CDCl₃) 1.92 (s, 3H, C5-CH₃), 2.20-2.52 (m, 2H, C2'H), 4.09 (m, 1H, C4'H), 4.49 (m, 1H, C3'H), 4.62 (s, 2H, OCH₂Ph), 4.70 (s, 2H, OCH₂Ph), 4.80 (s, 2H, OCH₂O), 5.50 (s, 2H, NCH₂O), 6.28 (t, 1H, C1'H) 7.24-7.51
20 (m, 11H, ArH, CH=), 9.65 (s, 1H, CHO). Anal. Calcd. for C₂₆H₂₈N₂O₇: C, 64.99; H, 5.87; N, 5.83. Found: C, 64.68; H, 5.95; N, 6.01.

D. 3-Benzylloxymethyl-3'-O-benzylloxymethyl-5'-deoxy-5'-N-(octa-decylamino)thymidine

25 A suspension of 3-benzylloxymethyl-3'-benzylloxymethylthymidine-5'-aldehyde (11 g, 23 mmol) and molecular sieve-4a (12 g) in tetrahydrofuran (250 ml) was treated with octadecylamine (8 g, 30 mmol) for 16 hrs at room temperature. The mixture was then treated with sodium
30 cyanoborohydride (95%, 2.2 g, 33 mmol) and let stir an additional 16 hrs. The reaction mixture was filtered, concentrated in vacuo, partitioned between EtOAc/H₂O, separated, dried and reconcentrated in vacuo. The resultant gum was chromatographed on silica gel to afford a white
35 powder. Recrystallization (MeOH) yielded the product, 3.8 g (23%). m.p. 60-62°C, ¹NMR (CDCl₃) .88 (m, 3H, CH₃), 1.22-1.51 (m, 35H, CH₂), 1.93 (s, 3H, C5-CH₃), 2.07 (ddd, 1H, C2'a),

2.46 (ddd, 1H, C2'b), 2.51-2.94 (m, 4H, CH₂NH, C5'H), 4.07 (m, 1H, C4'H), 4.28 (m, 1H, C3'H), 4.62 (s, 2H, OCH₂Ph), 4.70 (s, 2H, OCH₂Ph), 4.80 (s, 2H, OCH₂O), 5.50 (s, 2H, NCH₂O), 6.28 (t, 1H, C1'H), 7.25-7.40 (m, 11H, CH=,ArH). Anal. Calcd. for 5 C₄₄H₆₅N₃O₆: C, 72.19; H, 8.95; N, 5.74. Found: C, 71.88; H, 8.72; N, 6.01.

E. 3-Benzylloxymethyl-3'-O-benzylloxymethyl-5'-deoxy-5'-N-(octa-decylaminotrifluoroacetyl)thymidine

To a solution of 3-benzylloxymethyl-3'-O-
10 benzylloxymethyl-5'-deoxy-5'-N-(octadecylamino)thymidine (5.8 g, 79 mmol) and TEA (4.0 ml, 28 mmol) in CH₂CH₂ (150 ml) was added trifluoroacetic anhydride (1.2 ml, 85 mmol). After 2h, TLC indicated completeness of reaction. The reaction was concentrated in vacuo <40°C and coevaporated with MeOH (2x 25
15 ml). Chromatography on silica gel (EtOAc/hexane, 1/1) afforded the product, 6.4 g (98%). ¹H NMR (CDCl₃) .88 (m, 3H, CH₃), 1.25 (m, 32H, CH₂), 1.55 (m, 2H, CH₂CH₂NH), 1.93 (s, 3H, C5-CH₃), 2.10-2.51 (m, 4H, C2'H, CH₂NH), 3.22-3.82 (m, 2H, C5'H), 4.21 (m, 2H, C3'H, C4'H), 4.63 (s, 2H, OCH₂Ph), 4.70
20 (s, 2H, OCH₂Ph), 4.80 (s, 2H, OCH₂O), 5.50 (s, 2H, NCH₂O), 6.27 (t, 1H, C1'H), 7.23-7.41 (m, 11H, ArH); ¹⁹F NMR (CDCl₃) -74.68, (DMSO-d₆) -69.36. Anal. Calcd. for C₄₆H₆₆F₃N₃O₇: C, 66.56; H, 8.01; N, 5.06. Found: C, 66.41; H, 7.74; N, 5.29.

F. 5'-Deoxy-5-N-(octadecylaminotrifluoro-
25 acetyl)thymidine

A suspension of 3-benzylloxymethyl-3'-O-
benzylloxymethyl-5'-deoxy-5-N-
(octadecylaminotrifluoroacetyl)thymidine (5.5 g, 66 mmol) in
methanol (250 ml), acetone (35 ml), acetic acid (0.5 ml) and
30 palladium hydroxide/carbon (Pearlman's catalyst, 5.5 g) was hydrogenated in a paar bottle for 48 hrs at 50 psi. The catalyst was filtered off on a celite bed and the celite washed carefully with hot acetone (4 x 200 ml). The filtrates were combined, concentrated in vacuo to a solid and
35 recrystallized (MeOH) to afford the product, 3.2 g (82%).
m.p. 170-172 °C ¹H NMR (DMSO-d₆) 88 (m, 3H, CH₃), 1.23 (m, 32H, CH₂), 1.55 (m, 2H, CH₂CH₂NH), 1.80 (s, 3H, C5-CH₃), 2.07 (ddd,

1H, C2'a), 2.45 (ddd, 1H, C2'b), 3.30-3.87 (m, 6H, C2'H, CH₂CH₂NH, C5'CH₂), 3.96 (m, 1H, C4'H), 4.15 (m, 1H, C3'H), 5.20 (m, 1H, C3'OH), 6.18 (t, 1H, C1'H), (20°C) 7.50 (s, 1H, CH=) and 7.55 (s, 1H, CH=), (90°C) 7.40 (s, 1H, CH=), 11.31 (s, 5 1H, ArNH), ¹⁹F NMR (DMSO) -69.2. Anal. Calcd. for C₃₀H₅₀N₃O₅F₃: C, 61.10; H, 8.54; N, 7.12. Found: C, 60.93; H, 8.51; N, 7.34.

10 G. 5'-deoxy-5'-N-(octadecylaminotrifluoroacetyl)thymidine-3'-O-(2-cyanoethyl N,N-diisopropyl)phosphoramidite

A solution of 5'-deoxy-5'-N-(octadecylaminotrifluoroacetyl)thymidine (5.9g, 10 mmol) in dry THF (1000 ml) was treated with bis-N,N-diisopropylaminocynoethyl phosphite (8.0 g, mmol) and N,N-diisopropylaminotetrazolide (0.5 g, 15 cat. amount) at rm. temp. for 16 h. The reaction was concentrated in vacuo and the residue was chromatography on silica gel (hexane/EtOAc, 6/4) to afforded the product as a foam (5.1 g). ¹⁹F NMR (CDCl₃) -74.65; ³¹P NMR (CDCl₃) 149.63, 149.56.

20 EXAMPLE 9: SYNTHESIS OF CHOLESTEROL-OLIGONUCLEOTIDE CONJUGATES TARGETED TO MDR1

Mammalian cells selected for resistance to certain antitumor drugs often display cross resistance to other apparently unrelated drugs and are thus said to display a 25 multidrug resistant (MDR) phenotype (Bradley et al., *Cancer Metastasis Rev.*, 1994, 13, 223). One form of MDR is based on overexpression of one or more members of a family of membrane proteins (P-glycoproteins) which serve as ATP driven drug efflux pumps (Bradley et al., *Cancer Metastasis Rev.*, 1994, 30 13, 223; Gottesman et al., *J. Biol. Chem.*, 1988, 263, 12163; Roninson, *Biochem. Pharmacol.*, 1992, 43, 95). The human MDR (P-glycoprotein) gene family has two members, only one of which (P170, encoded by the MDR1 gene) appears to be responsible for resistance to cytotoxic drugs (Roninson, 35 *Biochem. Pharmacol.*, 1992, 43, 95). In highly drug-resistant

cells, P-glycoprotein message and protein levels can be many times greater than in their drug sensitive counterparts. Although MDR can be modulated by using a variety of agents that competitively inhibit P-glycoprotein mediated antitumor 5 drug efflux (Kaji et al., *Biochem.*, 1994, 33, 5041), several of these agents have proven less than ideal in clinical trials (Chabner et al., *J. Clin. Oncol.*, 1991, 9, 4).

A. Synthesis

5'-cholesterol conjugated oligonucleotides to the *MDR1* 10 sequence (Chen et al., *Cell*, 1986, 47, 381; Genbank accession No. AF016535) were synthesized as follows. Cholesterol-3-carboxyaminoethyl-B-cyanoethyl-N, N-diisopropylphosphoramidite was synthesized according to the procedure reported by MacKellar et al. (*Nucl. Acids Res.*, 1992, 20, 15 3411). 7.25 grams of this amidite was dissolved in anhydrous dichloromethane to bring the concentration to 0.1 M. Using this solution, ISIS 11073, a 5' cholesterol conjugated version of ISIS 5995, was synthesized by standard phosphoramidite chemistry to make an oligomer with a 20 phosphorothioate backbone. For the cholesterol amidite coupling step, reaction time was extended to 45 minutes. This resulted in 85% coupling for the cholesterol amidite. After standard deprotection, the oligonucleotide-cholesterol conjugate was purified on a C-4 reverse-phase HPLC column 25 (Manoharan et al., *Tetrahedron Lett.*, 1995, 36, 3651). ISIS 12064, a 5' cholesterol conjugated version of ISIS 10221, was synthesized and purified in the same manner.

Oligonucleotides comprising a 3'-O-alkylamino cholesterol moiety were prepared in the following manner. 30 3'-O-(propylthalimide)-cytidine was prepared essentially according to Examples 75 and 104 of WO 95/06659 (PCT/US94/10131, published March 9, 1995), with the exception that N-(5-bromopentyl)phthalimide was used in place of N-(3-bromopropyl)phthalimide in order to generate 3'-O- 35 (pentylphthlamide)-cytidine. From this compound, 5'-O-[dimethoxytrityl]-3'-O-[pentylamino]-cytidine was prepared by refluxing with hydrazine in methanol solvent. The product

was purified in a silica column using 98% methanol/ammonium hydroxide 2% solvent. 5'-O-[dimethoxytrityl]-3'-O-[pentylamino]-cytidine (1.5 g) was then treated with cholesterol choloformate (1.1 g) in a mixture of 10 ml 5 pyridine in 30 ml methylene chloride. After overnight stirring another 600 mg of cholesterol chloroformate was added and the reaction mixture was stirred for another four hours. Thin layer chromatography analysis showed reaction products at exocyclic amine and at 3'-O-pentylamine side 10 chain. The desired product, 3'-O-[pentylamino-carbonyl-oxy cholesteryl]-cytidine was obtained as the slower moving product in 43% yield.

600 mg of 3'-O-[pentylamino-carbonyl-oxy cholesteryl]-cytidine was coevaporated with pyridine (2x 10 ml) and then 15 dissolved in 10 ml of anhydrous pyridine. With external cooling using a ice bath, trimethylsilyl chloride (1 ml) was added using a syringe over a period of 5 minutes and the solution was stirred for 30 minutes. Then benzoylchloride (1 ml) was added followed by 10 ml of pyridine. The reaction 20 mixture was stirred at room temperature overnight. 4 ml of water was added with external cooling and after 30 minutes 4 ml of concentrated ammonium hydroxide (30%) was added. Stirring was continued for another 1 hour. The reaction mixture was then evaporated and extracted between methylene 25 chloride and water. The methylene chloride layer was evaporated to give 1.2 g of crude N⁴-benzoyl-3-O-[pentylamino carbonyl-oxy-cholesteryl]-cytidine which was then purified in a silica column using 2.5% methanol in chloroform. The product identity and homogeneity were confirmed by ¹³C and ¹H 30 NMR spectral studies.

N⁴-benzoyl-3-O-[pentylamino carbonyl-oxy-cholesteryl]-cytidine (450 mg) was added to 2 g of controlled pore glass (CPG, succinylated and capped), and to this mixture 200 mg of dimethylaminopyridine, 1 g of EDC (1-ethyl-3- 35 dimethylaminopropyl)carbodiimide hydrochloride), 400 µl of triethylamine and 10 ml pyridine were added. The mixture was shaken in a wrist-action shaker overnight. The CPG was then

filtered, washed with methylene chloride, methanol, methylene chloride and then ether. Then, 1.5 g of pentochlorophenol, 1 g EDC, 1 ml of triethylamine and 10 ml of pyridine were added to the CPG and the shaking was continued for 16 hours. Then 5 3 ml of pyperidine was added and shaking continued for 5 minutes. The CPG was filtered, washed and dried. 9 mg of the derivatized CPG was treated with 25 ml of 2% dichloroacetic acid in methylenechloride and the loading was determined to be 27.16 $\mu\text{mol/g}$ using colorimetric assays.

10 ISIS 13328 (GATCC*, where "C*" indicates the 3'-O-alkylamino cholesterol cytidine residue; used for NMR studies), ISIS 13329, ISIS 13330, ISIS 13331 and ISIS 13332 were synthesized using this CPG. Other 3'-O-alkylamino cholesterol derivatives, and 5'-fluorescein isothiocyanate (FITC)

15 conjugates of the oligonucleotides of the invention are prepared in like manner using the methods disclosed in WO 95/06659 and the above protocols.

TABLE 9

Phosphorothioate oligonucleotides targeted to MDR1

20	ISIS #	SEQUENCES* (DESCRIPTION)	SEQ ID NO:	TARGET REGION
	5990	GAG-CCG-CTA-CTC-GAA-TGA-GC	27	5' Untranslated
	5993	GTT-CTG-GCT-TCC-GTT-GCA-CC	28	5' Untranslated
	5994	CCC-GGC-CCG-GAT-TGA-CTG-AA	29	5' Untranslated
	5995	CCA-TCC-CGA-CCT-CGC-GCT-CC	30	Start codon
25	10440	CGG-TCC-CCT-TCA-AGA-TCC-AT	31	Start codon
	10441	CCC-CTT-CAA-GAT-CCA-TCC-CG	32	Start codon
	10442	CAA-GAT-CCA-TCC-CGA-CCT-CG	33	Start codon
	5996	CCT-GGT-CAT-GTC-TTC-CTC-CA	34	ORF** (splice junction)
	5997	CTT-TGC-CCA-GAC-AGC-AGC-TG	34	ORF (splice junction)
30	5998	GTT-CAC-TGG-CGC-TTT-GTT-CC	36	ORF / Stop codon
	5998	TGA-ACT-TGA-CTG-AGG-AAA-TG	37	3' Untranslated
	6002	CTT-GGA-AGA-GCC-GCT-ACT-CG	38	5' Cap region
	6003	GCC-GCT-ACT-CGA-ATG-AGC-GC	39	5' Cap region
	6004	GGA-AGA-GCC-GCT-ACT-CGA-AT	40	3' Untranslated
35	6005	CTC-TGT-TCC-TTT-AAT-TAC-GA	41	3' Untranslated
	6006	TCC-ACT-TGA-TGA-TGT-CTC-TC	42	3' Untranslated

	ISIS #	SEQUENCES* (DESCRIPTION)	SEQ ID NO:	TARGET REGION
20	6007	CTA-TGA-TTT-CTC-TCC-ACT-TG	43	3' Untranslated
	6010	GGC-AGT-CAG-TTA-CAG-TCC-AA	44	3' Untranslated
	6011	TTT-TAG-CAA-GGC-AGT-CAG-TT	45	3' Untranslated
	6012	TGC-AAA-CAT-TTC-AAT-ACT-TT	46	3' Untranslated
5	6013	AAG-TTT-AGT-TTT-ATT-ATA-GA	48	3' Untranslated
	10221	CAC-CAC-CCC-CCT-CGC-TGG-TC	48	Scrambled # 5995
	10222	CTC-CCG-CAC-ATC-TCC-GCG-CC	46	Scrambled # 5995
	11432	GCC-ACC-GTC-TGC-CCA-CTC-TG	50	ORF
	11433	GGC-ACG-TGC-AAT-GGC-GAT-CC	51	ORF
10	11434	CGG-AGC-CGC-TTG-GTG-AGG-AT	52	ORF
	11438	AGC-AGC-ATC-ATT-GGC-GAG-CC	50	ORF
	11439	CGG-CCA-TGG-CAC-CAA-AGA-CA	54	ORF
	11437	TGA-ACT-GAC-TTG-CCC-CAC-GG	55	ORF
	11438	GGG-ATG-TCC-GGT-CGG-GTG-GG	56	ORF
15	11439	TGC-CCA-CCA-GAG-CCA-GCG-TC	57	ORF
	11440	ATG-CCC-AGG-TGT-GCT-CGG-AG	54	ORF
	11441	GCC-TCC-TTT-GCT-GCC-CTC-AC	59	ORF
	11442	TGG-TGG-ACA-GGC-GGT-GAG-CA	60	ORF
	10443	2'-O-Methyl analog of # 5995	30	Start codon
20	11073	5'-Cholesterol analog of # 5995	30	Start codon
	12064	5'-Cholesterol analog of # 10221	48	Scrambled control for # 11073
	13758	2'-O-Methoxyethoxy analog of # 5995	30	Start codon
	13753	2'-Methoxyethoxy analog of # 10221	48	Scrambled control for # 13758
	13755	2'-Methoxyethoxy analog of # 5998	30	ORF / Stop codon
25	14429	2'-O-Methoxyethoxy CTT-ACC-CGC-TTG-TGT-TGC-TG	63	Scrambled control for # 13755
	13758	2'-Methoxyethoxy analog of # 6011	45	3' Untranslated
	13753	2'-Methoxyethoxy analog of # 6006	42	3' Untranslated
	12065	Analog of # 5995 comprising FITC at 3' end	30	Start codon
	13329	Analog of # 5995 comprising 3'-O-pentylamino cholesterol	30	Start codon
30	13330	Analog of # 5995 w/ 5'-C6 amino linker & 3'-O-pentylamino cholesterol	30	Start codon

20	ISIS #	SEQUENCES* (DESCRIPTION)	SEQ ID NO:	TARGET REGION
	13331	Analog of # 5995 comprising 5' FITC & 3'-O-pentylamino cholesterol	30	Start codon
	13332	Analog of # 10221 comprising 3'-O-pentylamino cholesterol	48	Scrambled control
	13409	Analog of # 5995 comprising 5'-C6 amino linker	30	Start codon
	13434	Analog of # 5995 comprising FITC at 5' end	30	Start codon

5 * From left to right, sequences are written from 5' to 3'.
All oligonucleotides contain fully substituted
phosphorothioate backbones unless otherwise indicated.

** ORF, open reading frame.

B. Oligonucleotide-mediated inhibition of MDR1 mRNA

10 NIH 3T3 cells transfected with a plasmid containing
the human MDR1 gene (pSK1 MDR) have been previously described
(Kane et al., Gene, 1989, 84, 439). These cells have proven
to be useful models for the study of multi-drug resistance
phenomena. Cells were grown in DMEM media containing 10%
15 fetal bovine serum (FBS) and 60 ng/ml colchicine in an
atmosphere of 95% air, 5% CO₂.

In most cases, the multi-drug resistant 3T3 cells were
exposed to oligonucleotides administered as a complex with
cationic liposomes (Lipofectin^R). However, all studies with
20 cholesterol conjugated oligonucleotides were performed in the
absence of cationic liposomes. Cells were treated with
oligonucleotides according to the following procedure. Cells
were grown in 162 mm flasks. When 95% confluency was
reached, cells were seeded onto 100 mm dishes at 5 x 10⁶/dish
25 in 10 ml of 10% FBS/DMEM and incubated for 24 hours. At this
stage, the cells were washed two times with phosphate
buffered saline (PBS) and then 8 ml of serum-free medium was
added. For phosphorothioate oligonucleotides, 20 ug/ml
LIPOFECTIN^R (GIBCO/BRL, Gaithersburg, MD) and various amounts
30 of oligonucleotide were mixed, pre-incubated at room
temperature for 30 minutes, and then incubated with the cells
at 37°C in a CO₂ incubator for various periods. Similar

methods were used for 2'-O-methyl phosphorothioate oligonucleotides. For treatments with cholesterol-phosphorothioate oligonucleotides, the compounds were simply added to the cells in serum free medium (in the absence of 5 LIPOFECTIN[®]) with antibiotics and incubated at 37°C in a CO₂ incubator for various periods. The cytotoxicity of the various treatments used in the oligonucleotide experiments were evaluated in preliminary experiments by using a vital dye assay. Unless otherwise noted, conditions were chosen 10 such that there was usually less than a 10% difference in the number of viable cells in samples treated with oligonucleotides versus control samples maintained in medium alone. The MDR-3T3 cells maintained a high level of viability during extended incubation in serum free medium, 15 although cell division was largely suppressed.

To measure MDR1 mRNA expression by Northern blotting, total cellular RNA was isolated by lysis in 4M guanidium isothiocyanate followed by a cesium chloride gradient, and the RNA was resolved on 1.2% agarose gels containing 1.2% 20 formaldehyde and transferred to nitrocellulose membranes (Dean et al., *J. Biol. Chem.*, 1994, 269, 16416). The blots were hybridized with a ³²P radiolabeled human MDR1 cDNA probe. The MDR1 cDNA probe was isolated by performing a polymerase chain reaction on the pSK1 MDR plasmid, as 25 described previously (Alahari et al., *Nucl. Acids Res.*, 1993, 21, 4079). The following oligonucleotide primers were used for PCR:

5'-GGATCTTGAAGGGGACCGCAATGGAGGAGC (SEQ ID NO: 61), and
5'-GTCCAACACTAAAAGCCCCAATTAATACAG (SEQ ID NO: 62).

30 The resulting fragment was checked on an agarose gel and was radiolabeled with ³²P-dCTP using a commercially available random primer labeling kit (Amersham, Arlington Heights, IL) according to the manufacturer's instructions. The filters were hybridized overnight in hybridization buffer (25 mM KPO₄, 35 pH 7.4; 5x SSC; 5x Denhardt's solution, 100 ug/ml Salmon

sperm DNA and 50% formamide) (Alahari et al., *Nucl. Acids Res.*, 1993, 21, 4079). This was followed by two washes with 1x SSC, 0.1% SDS and two washes with 0.25x SSC, 0.1% SDS. Hybridizing bands were visualized by exposure to X-OMAT AR 5 film and quantitated using a PhosphorImager™ (Molecular Dynamics, Sunnyvale, CA). To confirm equal loading of RNA, the blots were stripped and reprobed with a ³²P-labeled beta-actin probe (Clontech, Palo Alto, CA).

1. Identification of an antisense
oligonucleotide that specifically reduces
MDR1 message expression

RNA isolated from MDR 3T3 cells was probed with a 1.0 kb PCR-based MDR1 probe; this revealed a transcript of 4.4 kb. In initial experiments, the MDR 3T3 cells were exposed to 1.0 μ m concentrations of several different antisense oligonucleotides, or control oligonucleotides, in the presence of 20 ug/ml LIPOFECTIN^R for 24 hours. One oligonucleotide, ISIS 5995, which was targeted to a region overlapping the AUG codon, caused about 50% reduction in MDR1 message levels (Table 10). Oligonucleotides ISIS 10221 and ISIS 10222 have the same base composition as ISIS 5995, but are "scrambled" sequences that were used as specificity controls. NIH 3T3 cells transfected with pSK1 MDR plasmid were grown to 90% confluence and treated with oligonucleotide (1 μ m) for 24 hours in the presence of Lipofectin^R in serum free medium. Total RNA was isolated and fractionated on agarose formaldehyde gels and blotted onto nitrocellulose membranes. These membranes were probed with a ³²P radiolabeled 1.0 kb MDR1 cDNA, and then stripped and reprobed with a ³²P radiolabeled beta-actin cDNA probe to confirm equal loading of RNA, allowing the levels of MDR1 transcripts to be normalized with regard to the beta-actin bands. Transcript levels were quantitated using a PHOSPHORIMAGER™ (Molecular Dynamics, Sunnyvale, CA); the values are expressed in arbitrary units (the beta-actin transcripts were essentially constant).

TABLE 10:

MODULATION OF MDR1 mRNA BY ANTISENSE OLIGONUCLEOTIDES			
		MDR1 mRNA Level	
ISIS No.	SEQ ID NO:	(arbitrary units)	% Control
None*	----	473,913	100%
5 LIPOFECTIN ^R	----	430,435	91%
5990	27	443,478	94%
5995	30	226,087	48%
10221	48	456,522	96%
10222	49	406,522	86%

* Control = untreated cells			

This experiment was repeated several times, and the MDR1 and beta-actin bands on non-saturated autoradiograms were compared by laser densitometry. The MDR1/beta-actin ratios for the ISIS 5995 and ISIS 10221 oligonucleotides were 0.49 and 1.01, respectively, indicating specific inhibition of MDR1 message levels by ISIS 5995.

2. Time course of inhibition of MDR1 message levels by oligonucleotide ISIS 5995

In order to evaluate the time course of ISIS 5995-mediated MDR1 modulation, transfected cells were treated with 1 μ m ISIS 5995, or 1 μ m ISIS 10221, for 24, 48 and 72 hours. MDR1 and beta-actin RNA levels were examined as described above. Maximum specific reduction of MDR1 mRNA was observed after 24 hours treatment of cells with ISIS 5995; longer treatment did not result in lower mRNA levels. With these unmodified oligonucleotides, reduction of MDR1 mRNA levels was attained only when oligonucleotide treatment was performed in serum free medium, and when cationic liposomes were used. This result is consistent with previous observations on antisense actions of phosphorothioate oligonucleotides in cell culture (Bennett et al., *Mol. Pharm.*, 1992, 41, 1023; Manoharan et al., *Tetrahedron Lett.*, 1995, 36, 3651). Multiple treatments with ISIS 5995 oligonucleotide did not cause any greater specific reduction

in MDR1 message levels than a single treatment, while greater cytotoxicity was observed. The reduction in MDR1 mRNA expression was reversible, since, after 24 hours exposure to ISIS 5995, cells returned to culture medium without oligonucleotide demonstrated normal levels of MDR1 mRNA within 24 hours.

3. Concentration dependence of MDR1 message reduction

Treatment of multi-drug resistant 3T3 cells with oligonucleotide ISIS 5995 resulted in a concentration-dependent inhibition of MDR1 message (Figure 1). Some reduction in message levels was observed with concentrations as low as 100 nM. Maximal specific effects were observed at approximately 1.0 μ M; this entailed an approximately 60% reduction in MDR1 message. Use of higher concentrations of oligonucleotides (5-10 μ M) with Lipofectin^R resulted in greater non-specific effects, i.e., reduced beta-actin message levels and increased cytotoxicity, which were observed with both ISIS 5995 and ISIS 10221 (the scrambled control).

C. Oligonucleotide-mediated inhibition of P-glycoprotein

Transfected MDR NIH 3T3 cells were grown and treated with oligonucleotides as described in Example (9)(B). In order to measure P-glycoprotein expression by Western blotting, cells were seeded in 60 mm dishes at 1.2×10^6 per dish and incubated for 24 hours in serum containing medium. The cells were treated with the oligomers for various times in serum free medium as described above. Cells were then extracted in lysis buffer (20 mM Tris, pH 7.5, 2 mM EDTA, 500 mM EGTA, 2 mM PMSF, 1 mM DTT, aprotinin (10 ug/ml), 0.5% Triton-X) and sonicated briefly. The lysate was spun in a microfuge tube for 20 minutes at 4°C and the resulting supernatant was checked for protein content. Equal amounts of protein (usually 20 ug) were mixed with SDS sample buffer and boiled. Protein samples were separated by 8% SDS PAGE

and the resolved proteins were electrophoretically transferred onto polyvinylidene fluoride membranes (Millipore, Bedford, MA). The membranes were blocked (with 3% BSA, 2% non fat dry milk in PBS) and then treated with 2.5 ug/ml C219 anti-P-glycoprotein antibody (Signet, Dedham, MA). After washing three times with 0.1% Tween 20, the membranes were incubated with rabbit anti-mouse antibody (Cappel, Durham, NC). Immunoreactive proteins were visualized either by ECL (Enhanced Chemiluminescence, Amersham, Arlington Heights, IL) or with ¹²⁵I secondary antibodies.

Expression of the P-glycoprotein was reduced upon treatment of the multidrug resistant 3T3 cells with the ISIS 5995 oligomer, consistent with the Northern blot analyses of mRNA levels. In the Western assays, P-glycoprotein was reduced at least 80% by treatment with ISIS 5995 and about 50% by ISIS 10440. In contrast, scrambled control oligomer ISIS 10221 did not reduce P-glycoprotein expression. The decrease in P-glycoprotein expression was minimal after 24 hours, readily detectable by 48 hours, and reached a maximum only after 72 hours exposure. Thus, effects at the protein level lag behind the observed reduction in message levels. This observation is consistent with the fact that the P-glycoprotein is quite stable and normally turns over rather slowly with a $t^{1/2}$ of 48-72 hours (Richert et al., *Biochem.*, 1988, 28, 7607).

D. Effects of a cholesterol derivative of oligonucleotide 5995 on MDR1 message levels and P-glycoprotein expression

A 5'-cholesterol derivative of ISIS 5995 (ISIS 11073), as well as a 5'- cholesterol derivative of the scrambled control oligonucleotide ISIS 10221 (ISIS 12064), were synthesized and their effects on MDR1 message and P-glycoprotein levels were examined. As is explained below, 3'- cholesterol derivatives were also prepared and tested.

Transfected MDR NIH 3T3 cells were grown and treated with oligonucleotides as described in Example (9)(B). MDR1 mRNA expression was measured by Northern blotting as

described in Example (9) (C). In order to measure cell surface P-glycoprotein levels by flow cytometry, cells were seeded in 60mm dishes at 1.2×10^6 /plate in 5 ml of medium, grown for one day in 10% FBS/DMEM, and exposed to the 5 oligomers in serum free medium. After treatment with the oligonucleotides, cells were washed twice in PBS, 0.25 ml of pancreatin was added to remove cells from the plate, and the dispersed cells were resuspended in 10% FBS/DMEM and incubated at 37°C for 2 hours. After the incubation, cells 10 were washed in PBS, and 50 μ l of 20 ug/ml MRK16 anti-P-glycoprotein antibody (Kamiya, Thousand Oaks, CA) was added (Ishida et al., *Jpn. J. Cancer Res.*, 1989, 80, 1006). This mixture was incubated for 45 minutes on ice and cells were washed three times in 10% FBS/PBS. Cells were then incubated 15 for 30 minutes with 20 μ l of ten times diluted secondary antibody, a R-phycoerythrin (R-PE) conjugated goat anti-mouse IgG (Sigma, St. Louis, MO). After the incubation, cells were washed two times in 10% FBS/PBS. Finally, the cells were resuspended in 500 μ l of PBS. The level of R-PE fluorescence 20 in viable cells (as determined by light scatter) was quantitated using the Cicero software application (Cytomation, Fort Collins, CO) on a Becton Dickinson flow cytometer.

Table 11 shows the effect of cholesterol-conjugated 25 phosphothioate oligonucleotides on MDR1 mRNA expression. MDR-3T3 cells were treated with various concentrations of oligonucleotides ISIS 11073 (5'-cholesterol 5995) or ISIS 12064 (5'-cholesterol 10221; scrambled control) for 24 hours in serum free medium. Total RNA was isolated, fractionated 30 and probed with a MDR1 cDNA fragment; the same blot was stripped and reprobed with a beta-actin probe. The results were quantitated using a PHOSPHORIMAGER™; the ratio of MDR1 to beta-actin message is indicated in the table. As shown in Table 11, treatment with concentrations of ISIS 11073 35 (cholesterol 5995) in the 250 nM to 2.5 μ M range, resulted in a specific decrease in levels of MDR1 message. It is important to note that at least about 60% inhibition of MDR1

mRNA expression was attained with ISIS 11073 without the use of cationic liposomes.

TABLE 11:
MODULATION OF MDR1 mRNA BY CHOLESTEROL-CONJUGATED
ANTISENSE OLIGONUCLEOTIDES

ISIS No.	SEQ ID NO:	Conc.	Ratio of MDR1 mRNA to beta-actin mRNA
None*	----	----	1.00
12064	48	2.5 uM	1.10
11073	30	250 nM	0.48
11073	30	500 nM	0.38
11073	30	1.0 uM	0.45
11073	30	2.5 uM	0.59

* Control = untreated cells

Lane 1, untreated cells; lane 2, cells treated with 2.5 μ M 5' ISIS 12064; lanes 3-6, cells treated with ISIS 11073 at concentrations of 250 nM, 500 nM, 1.0 μ M and 2.5 μ M, respectively.

To observe the effects of the 5'-cholesterol 5995 (ISIS 11073) oligonucleotide on the expression of P-glycoprotein at the cell surface, immunofluorescent staining and flow cytometry were utilized. Treatment of multidrug resistant 3T3 cells with increasing concentrations of ISIS

11073 over the range of 0.5-2.5 μm resulted in a progressive reduction in surface expression of P-glycoprotein to about 40% of control levels. Some non-specific reduction of P-glycoprotein expression was also observed with the scrambled control oligomer (5'-cholesterol 10221, ISIS 12064), but the effect of the antisense compound was greater at all concentrations tested. In a parallel experiment, the effect of 1 μm ISIS 5995 or ISIS 10221 administered with LIPOFECTIN^R on P-glycoprotein surface expression was examined. The test concentrations of antisense (ISIS 5995) or scrambled 5'-cholesterol (ISIS 10221) phosphorothioate oligonucleotides, administered with LIPOFECTIN^R, were less effective than an equivalent concentration of the cholesterol-conjugated analogs. Thus, the cholesterol phosphorothioate antisense compound given alone is at least as effective as the phosphorothioate antisense compound administered with cationic liposomes. Moreover, the cholesterol oligonucleotides showed less experiment-to-experiment variation than did the standard phosphorothioate oligonucleotides when administered with cationic lipids.

To observe the effects of the 3'-cholesterol 5995 oligonucleotide (ISIS 13329) on the expression of P-glycoprotein at the cell surface, immunofluorescent staining and flow cytometry were utilized as described above. Treatment of multidrug resistant 3T3 cells with increasing concentrations of ISIS 13329 over the range of 0.5-2.5 μm resulted in a progressive reduction in surface expression of P-glycoprotein to about 50% of control levels. In a parallel experiment, the effect of 1 μm ISIS 5995 or ISIS 13332 administered with LIPOFECTIN^R on P-glycoprotein surface expression was examined. The test concentrations of antisense (ISIS 5995) or scrambled 3'-cholesterol (ISIS 13332) phosphorothioate oligonucleotides administered with LIPOFECTIN^R, were less effective than an equivalent concentration of the cholesterol-conjugated analogs. Thus, the cholesterol phosphorothioate antisense compound given alone is at least as effective as the phosphorothioate

antisense compound administered with cationic liposomes. However, the cholesterol oligonucleotides showed less experiment-to-experiment variation than did the standard phosphorothioate oligonucleotides when administered with
5 cationic lipids and are thus preferred. A further advantage of the 3'-cholesterol oligonucleotide is stability to 3'-exonucleases.

E. Effects of oligonucleotides on Rh 123
accumulation

- 10 Rhodamine 123 is fluorescent dye that is a substrate for P-glycoprotein and is rapidly transported out of multi-drug resistant cells. Thus, Rh 123 uptake can be employed as a simple and convenient way of assessing the impact of various treatments on the multi-drug resistance phenotype.
- 15 In order to measure Rhodamine 123 uptake by flow cytometry, the procedure described by Twentyman et al. (*Eur. J. Cancer*, 1994, 30, 1360) was followed with minor changes. Briefly, 7.5×10^5 cells were seeded on 6 well plates, incubated for one day, and treated with oligomers as described above.
- 20 Cells were removed with pancreatin and resuspended in 10% FBS/DMEM. Rhodamine 123 (Sigma, St. Louis, MO) was dissolved in water, added to a final concentration of 1.0 ug/ml; 500 μ l samples were taken at several points, washed with medium once, and resuspended in 500 μ l of media. Viable cells were
25 analyzed for the accumulation of Rhodamine 123 on a Becton Dickinson flow cytometer using Cicero software.

Treatment of multi-drug resistant 3T3 cells with increasing concentrations of ISIS 11073 (cholesterol-conjugated ISIS 5995) resulted in a progressive decrease in
30 P-glycoprotein expression (Figure 2) that paralleled an increase in Rh 123 accumulation (Figure 3). As in the case of P-glycoprotein expression, some non-specific effect was also observed with the scrambled control oligomer (ISIS 12064; cholesterol-conjugated ISIS 10221); however, the
35 effect of the antisense compound was significantly greater.

EXAMPLE 10: UPTAKE AND INTRACELLULAR DISTRIBUTION OF
CHOLESTEROL-CONJUGATED OLIGONUCLEOTIDES

As Example 9 demonstrates, experiments indicated that the 3'-cholesterol derivative of ISIS 5995 (ISIS 13329) had an equivalent effect on P-glycoprotein expression as 5'-cholesterol 5995 (ISIS 11073). To determine the rate of cellular uptake and intracellular distribution of MDR1 antisense oligonucleotides, the following experiments were performed with 5'-FITC, 3'-cholesterol oligonucleotides.

10 The cellular accumulation of FITC labeled oligonucleotides was quantitated by flow cytometry. The cell uptake and intracellular distribution was visualized on a cell-by-cell basis using digitized fluorescence microscopy, essentially as described previously (Shoji et al., *Nucl.*
15 *Acids Res.*, 1991, 19, 5543), except that a confocal microscope system was used. Intracellular fluorescence was visualized by taking optical sections through the cell body; a section approximately half way between the top surface of the cells and the surface of the cover slip was examined in
20 each case. Phase contrast images of the same cells were also obtained. A Nikon Fluor 40/1.3 Oil Ph4DL objective was used, with Comos software controlling a Biorad MRC600 scanner/laser. In digitized images, gain and black level settings were optimized on cells treated with free FITC 5995
25 oligomer and were unchanged thereafter.

Incubation conditions for the flow cytometry and confocal microscopy experiments were as follows. MDR 3T3 cells were treated with 1 μ m ISIS 13331 (5'-FITC, 3'-cholesterol 5995), or with 1 μ m ISIS 13434 (5'-FITC 5995)
30 with or without LIPOFECTIN^R, for either 2 hours (Figure 4) or 18 hours (Figure 5) in serum free medium at 37°C. Cells were harvested and the fluorescence profiles were determined using a flow cytometer; light scatter parameters were set so as to exclude non-viable cells. In the case of the 18 hour
35 treatment with LIPOFECTIN^R there were some cells with very high levels (above 10^4 units) of fluorescence; these were

accumulated in one channel and are shown as a vertical line at the right hand margin of the plot (Figure 5). Cells plated on glass coverslips were treated as above for 18 hour and then examined by confocal microscopy as described above.

5 As seen in Figure 4, during a 2 hour incubation period the cholesterol conjugated oligonucleotide (ISIS 13331) was rapidly accumulated by cells, while both free ISIS 13434, and ISIS 13434 complexed with LIPOFECTIN^R, accumulated to a far lesser degree. The cellular accumulation of the 3'-
10 cholesterol conjugated 5995 (ISIS 13331) was approximately 40 fold greater than ISIS 13434 at 2 hours. After overnight incubation (Figure 5), the free ISIS 13434 still displayed significantly less cell accumulation than ISIS 13331. The LIPOFECTIN^R complexed ISIS 13434 displayed substantial, but
15 very heterogeneous, cell uptake after overnight incubation. Based on previous experience with stability of phosphorothioates (Akhtar et al., *Trends in Cell Biology*, 1992, 2, 139) it is believed that most of the fluorescence accumulated represents FITC-conjugated oligonucleotide rather
20 than free FITC.

Confocal microscopic images essentially confirmed and extended the flow cytometry observations. Very little intracellular accumulation was seen with ISIS 13434. The cells treated with ISIS 13434 complexed with Lipofectin^R
25 showed extensive, but very heterogeneous, cellular uptake, with some cells heavily stained and others essentially blank; there was also a background of LIPOFECTIN^R particles plus associated oligonucleotide bound to the cover slip. Some of the cells treated with Lipofectin^R showed nuclear accumulation
30 of the fluorescence. The cells treated with ISIS 13331 (5'-FITC, 3'-cholesterol) oligonucleotide uniformly displayed extensive fluorescence in both the cytoplasm and nucleus. These observations demonstrate that the cholesterol conjugation has enhanced the rapidity, amount, and uniformity
35 of cellular uptake of the oligonucleotide, and leads to substantial cytoplasmic and nuclear accumulation.

EXAMPLE 11: EFFECTS OF 3'-CHOLESTEROL, 2'-METHOXYETHOXY
GAPMER OLIGONUCLEOTIDES ON P-GLYCOPROTEIN
EXPRESSION

5 A. Effects of 2'-methoxyethoxyoligonucleotides on
 P-glycoprotein expression

 2'-Methoxyethoxy derivatives of ISIS 5995 (ISIS 13758,
targeted to the start codon region of MDR1), ISIS 5998 (ISIS
13755, targeted to the stop codon region of MDR1) and ISIS
10221 (ISIS 13753, a scrambled control for ISIS 5995) were
10 prepared and examined for their ability to modulate P-
glycoprotein expression. To assay activity, experiments were
conducted essentially as described for Figure 2 (Example 9).
These oligonucleotides are "chimeric" or "gapped" compounds
having 2'-methoxyethoxy modifications on the five 5' and five
15 3' nucleotides, wherein each methoxyethoxy cytosine is a 5-
methyl cytosine, and phosphorothioate deoxynucleotides in the
center ten nucleotides of the molecules. This configuration
allows the oligonucleotide to have nuclease-resistant "wings"
while retaining a central portion that supports the action of
20 RNase H.

 As is shown in Figure 6, the 2'-methoxyethoxy
derivative of ISIS 5995 (ISIS 13758) exhibited an enhanced
ability to inhibit P-glycoprotein expression (compare with
Figure 2). Furthermore, ISIS 13755, the 2'-methoxyethoxy
25 derivative of ISIS 5998, exhibited significant activity in
these assays, even though the parent compound had an
unpromising effect on MDR1 mRNA expression (Example 9(B)).
These results are an example of the enhanced efficacy of
oligonucleotide activity that can be achieved by
30 incorporating methoxyethoxy modifications into
oligonucleotides. Although not wishing to be bound by any
particular theory, these results are believed to demonstrate
the enhanced activity resulting from the ability of
methoxyethoxy modifications to render oligonucleotides
35 resistant to many nucleases, as well as their ability to

increase the hybridization affinity of oligonucleotides to their targeted nucleic acid (i.e., RNA or DNA) molecules.

B. Cholesterol-conjugated 2'-methoxyethoxy oligonucleotides

5 Cholesterol is conjugated to ISIS 13758 (2'-methoxyethoxy targeted to the translation start codon region), ISIS 13753 (2'-methoxyethoxy scrambled control for ISIS 13758), ISIS 13755 (2'-methoxyethoxy targeted to the translation termination codon region) and ISIS 14429 (2'-
10 methoxyethoxy scrambled control for ISIS 13755) using 3'-O-[pentylamino-carbonyl-oxy-cholesteryl]-cytidine CPG as described above. Biological assays are conducted as described in Example 9. These phosphorothioate oligonucleotides are chimeric compounds having a 3'-
15 cholesterol (for cellular uptake and nuclease resistance), 2'-methoxyethoxy modifications in their flanks (for better binding to the target nucleic acid and for nuclease resistance), and 2'-deoxy nucleotides in the center 10 nucleotide region (the "gap"). This configuration allows the
20 chimeric oligonucleotide to have nuclease-resistant, high affinity "wings" while retaining an unmodified central "gap" that supports the action of RNase H when the oligonucleotide is bound to a target RNA molecule. Placing the cholesterol moiety at the 3'-terminus of the 3' oligonucleotide ensures
25 resistance to 3' exonucleases, enhances cellular uptake, and leaves the 5'-terminus available for conjugation of additional functional groups.

EXAMPLE 12: PLASMA UPTAKE AND TISSUE DISTRIBUTION OF ACTIVE OLIGONUCLEOTIDES IN MICE

30 The oligonucleotide Oligomer 71 (SEQ ID NO:20) from Example 7(C) was used as a first test oligonucleotide. This oligonucleotide is identified in the figures as ISIS 8005. Further oligonucleotide of the same sequence were prepared in the same manner. These further oligonucleotides include a
35 phosphorothioate oligonucleotide identified in the figures as

ISIS 3082 and an oligonucleotide incorporating a C₁₈ alkyl group linked to the 5' position of the nucleotides via a 5' amino group (prepared utilizing the compound of Example 8(G) in the same manner as per the procedure of Example 7(C)) identified in the figures as Isis 9047. The oligonucleotides were tritiated as per the procedure of Graham et al. (*Nuc. Acids Res.*, 1993, 16, 3737-3743).

A. Animals and Experimental Procedure

For each oligonucleotide studied, twenty male Balb/c mice (Charles River Laboratories, Inc., Wilmington, MA), weighing about 25 gm, were randomly assigned into one of four treatment groups. Following a one-week acclimation, mice received a single tail vein injection of ³H-radiolabeled oligonucleotide (approximately 750 nmoles/kg; ranging from 124-170 μ Ci/kg) administered in phosphate buffered saline, pH 7.0. The concentration of oligonucleotide in the dosing solution was approximately 60 μ M. One retro-orbital bleed (at either 0.25, 0.5, 2, or 4 hours post-dose) and a terminal bleed (either 1, 3, 8 or 24 hours post-dose) was collected from each group. The terminal bleed was collected by cardiac puncture following ketamine/xylazine anesthesia. An aliquot of each blood sample was reserved for radioactivity determination and the remaining blood was transferred to an EDTA-coated collection tube and centrifuged to obtain plasma. Urine and feces were collected at intervals (0-4, 4-8 and 8-24 hours) from the group terminated at 24 hours.

At termination, the liver, kidneys, spleen, lungs, heart, brain, sample of skeletal muscle, portion of the small intestine, sample of skin, pancreas, bone (both femurs containing marrow) and two lymph nodes were collected from each mouse and weighed. Feces were weighed, then homogenized 1:1 with distilled water using a Brinkmann Polytron homogenizer (Westbury, NY). Plasma, tissues, urine and feces homogenate were divided for the analysis of radioactivity by combustion and for determination of intact oligonucleotide content. All samples were immediately frozen on dry ice after collection and stored at -80°C until analysis.

B. Analysis of Radioactivity in Plasma, Tissue, and Excreta

Plasma and urine samples were weighed directly into scintillation vials and analyzed directly by liquid scintillation counting after the addition of 15 ml of BetaBlend (ICN Biomedicals, Costa Mesa, CA). All other samples (tissues, blood and homogenized feces) were weighed into combustion boats and oxidized in a Biological Materials Oxidizer (Model OX-100; R. J. Harvey Instrument Corp., Hillsdale, NJ). The $^3\text{H}_2\text{O}$ was collected in 20 ml of cocktail, composed of 15 ml of BetaBlend and 5 ml of Harvey Tritium Cocktail (R. J. Harvey Instrument Corp., Hillsdale, NJ). The combustion efficiency was determined daily by combustion of samples spiked with a solution of ^3H -mannitol and ranged between 73.9 - 88.3 %. Liquid scintillation counting was performed using a Beckman LS 9800 or LS 6500 Liquid Scintillation System (Beckman Instruments, Fullerton, CA). Samples were counted for 10 minutes with automatic quench correction. Disintegration per minute values were corrected for the efficiency of the combustion process.

C. Analysis of Data

Radioactivity in samples was expressed as disintegrations per minute per gram of sample. These values were divided by the specific activity of the radiolabel to express the data in nanomole-equivalents of total oligonucleotide per gram of sample, then converted to percent of dose administered per organ or tissue. Assuming a tissue density of 1 gm/ml, the nmole/gram data were converted to a total μM concentration. To calculate the concentration of intact oligonucleotide in plasma, liver or kidney at each time point, the mean total μM concentrations were divided by the percent of intact oligonucleotide in the dosing solution (82-97%), then multiplied by the mean percentage of intact oligonucleotide at each time point as determined by CGE or HPLC. These data was then used for the calculation of tissue half-lives by linear regression and to compare the plasma pharmacokinetics of the different modified oligonucleotides.

The pharmacokinetic parameters were determined using PCNONLIN 4.0 (Statistical Consultants, Inc., Apex, NC). After examination of the data, a one-compartment bolus input, first order output model (library model 1) was selected for use.

5 D. Plasma Uptake and Biodistribution Results

The result of the animal plasma uptake and tissue distribution tests are illustrated graphically in Figures 7 to 10. As is seen in Figure 7, plasma concentration of each of the test oligonucleotides decrease from the initial
10 injection levels to lower levels over the twenty-four hour test period. Plasma concentrations of the two oligonucleotides bearing conjugate groups of the invention were maintained at a higher level for a longer period than were those of the non-conjugate bearing phosphorothioate.
15 All of the test compounds were taken up from the plasma to tissues as is shown in Figures 8, 9 and 10. The two compounds of the invention had different distribution between the various tissues. Figure 8 shows the tissue distribution of the unconjugated phosphorothioate oligonucleotide, ISIS
20 3082. Figure 9 shows the tissue distribution of oligonucleotide ISIS 9047 (identical to ISIS 3082 but having a C₁₈ amine moiety conjugated to the 5' terminal residue), while Figure 10 shows the tissue distribution of oligonucleotide ISIS 8005 (also derived from ISIS 3082 and
25 having a cholesteryl moiety conjugated to the 5' terminal residue). The distribution of 5'-C₁₈ amine antisense oligonucleotide (ISIS 9047) was similar to that of parent compound ISIS 3082 except for an increase in distribution to the liver and a somewhat longer retention in plasma. Both of
30 these attributes were further enhanced in the case of the 5'-cholesteryl antisense oligonucleotide, with the amount of hepatic signal continuing to increase for at least 24 hours after dosing.

35 E. Modulation of ICAM-1 Expression in the Mammalian Liver by 5'-Cholesterol-Conjugated Antisense Oligonucleotides

The results from the animal plasma uptake and tissue distribution studies indicate that ISIS 8005, a 5'-cholesterol-conjugated antisense oligonucleotide targeted to murine ICAM-1, preferentially accumulates in murine livers following i.v. administration. In order to determine if this preferential accumulation results in enhanced modulation of ICAM-1 in the mammalian liver, the following experiments were done.

Mice were treated with oligonucleotides and examined as follows. First, 10 to 30 mg/kg of oligonucleotide (or a control solution) were administered (i.v.) to each mouse 24 and 2 hours prior to LPS treatment (Figure 11 shows results with 30 mg/kg doses). Then, to induce ICAM-1 expression, bacterial lipopolysaccharide (LPS) was injected into the mice. After 2 hours, the mice were sacrificed, and particular organs, or specific portion thereof, were removed for further study. RNA was prepared from isolated, homogenized tissues essentially according to the guanidinium/CsCl purification method of Chirgwin et al. (Biochemistry, 979, 18, 5294), electrophoresed and transferred to nylon membranes for hybridization studies (Northern analysis) according to methods well known in the art. In order to detect mouse ICAM-1 mRNA, a radiolabelled probe was prepared by random oligonucleotide-primed synthesis using a mouse ICAM-1 clone as a template. The blots were stripped and reprobed with a ³²P-labeled glyceraldehyde 3-phosphate dehydrogenase (G3PDH) probe (Clontech Laboratories, Inc., Palo Alto, CA) in order to confirm equal loading of RNA and to allow the levels of ICAM-1 transcripts to be normalized with regard to the G3PDH signals. Hybridizing bands were visualized by exposure to X-OMAT AR film and quantitated using a PHOSPHORIMAGER™ essentially according to the manufacturer's instructions (Molecular Dynamics, Sunnyvale, CA).

As shown in Figure 11, LPS induced ICAM-1 mRNA levels in the murine liver by at least one order of magnitude relative to untreated animals ("BASAL") whether administered

i.v. ("LPS-IV") or i.p. ("LPS-IP"). At the given dosages, in the absence of an uptake facilitator, ISIS 3082 ("3082-30," indicating 30 mg/kg of ISIS 3082) was unable to reverse the LPS-mediated induction of ICAM-1 mRNA in the liver. In contrast, under these conditions, ISIS 8005 ("8005-30"), a 5'-conjugated cholesterol derivative of ISIS 3082, reduced the amount of hepatic ICAM-1 mRNA by about 50% relative to the amount present in the livers of animals to which LPS, but not oligonucleotide, was administered. A control 5'-cholesterol conjugated scrambled oligonucleotide, ISIS 13293, had no apparent effect on induced ICAM-1 levels.

In similar experiments, the sequence (gene target) specificity of the 5'-cholesterol antisense oligonucleotide ISIS 8005 was examined. ISIS 8005, which is targeted to ICAM-1, had no effect on the levels of mRNA derived from the oncogene c-raf or encoding the cellular adhesion molecule PECAM-1 which is related to, yet distinct from, ICAM-1. As shown in Figure 12, the 5'-cholesterol 3082 analog had no discernable effect on c-raf or PECAM-1 mRNA levels.

To determine if the antisense-mediated inhibition of ICAM-1 mRNA in the mammalian liver is organ-specific, levels of ICAM-1 mRNA in lung samples from the sacrificed animals used in the experiments described above were examined by Northern assays. As is shown in Figure 13, administration of LPS induced ICAM-1 mRNA levels in the lung, albeit to a lesser degree than seen in liver samples. In any event, neither ISIS 3082 nor its 5'-cholesterol conjugate ISIS 8005 was able to reverse the LPS-mediated induction of ICAM-1 to any great degree under these conditions.

Immunohistological sections of isolated liver samples were prepared and stained using primary antibodies specific for ICAM-1 and secondary antibodies conjugated to horse radish peroxidase (HRP). As shown in Figure 14, the cross-section from untreated livers ("Basal") is virtually indistinguishable from livers treated with the ICAM-1 inducer LPS and the 5'-cholesterol conjugated ICAM-1-targeted antisense oligonucleotide ISIS 8005 (two left panels). In

contrast, livers induced by LPS and treated with ISIS 13293, a 5'-cholesterol conjugated scrambled control (5'-GCG-TTG-CTC-TTC-TTC-TTG-CG, SEQ ID NO:64) phosphorothioate oligonucleotide for ISIS 8005 appear quite dark (two panels 5 on right) due to the signal resulting from HRP bound (via a series of antibodies) to ICAM-1. These results indicate that levels of the ICAM-1 protein in the mammalian liver can, like the levels of ICAM-1 mRNA in livers, be modulated by a cholesterol-conjugated antisense oligonucleotide in a 10 sequence-specific manner. Moreover, comparison of the overall cellular structure in the untreated ("basal") livers to LPS- and ISIS 8005-treated reveals that there are no gross cellular defects resulting from antisense-mediated reversal of ICAM-1 induction.

15 For comparison's sake, ISIS 9388, a 3'-cholesterol-conjugated derivative of ISIS 3082 (SEQ ID NO:20), was also prepared. Specifically, ISIS 9388 contains a 3' terminal 3'-O-hexylamino cholesteryl moiety introduced into the oligonucleotide during synthesis using the phosphoramidite 20 from Example 4(B) and other methods disclosed herein. ISIS 9388, and some associated control compounds, were tested for their ability to modulate ICAM-1 mRNA levels in murine livers according to the preceding methods. The results, shown in Figure 15, demonstrate that, like the 5'-cholesterol 25 conjugate (ISIS 8005), the 3'-cholesterol conjugate (ISIS 9388) is able to reduce ICAM-1 mRNA levels by about 50% under these conditions (i.e., a dosage of 10 mg/kg of oligonucleotide).

The results in this Example demonstrate that 30 cholesterol-conjugated antisense oligonucleotides are preferentially taken up by cultured mammalian cells *in vitro* and targeted to the mammalian liver *in vivo*. Furthermore, the oligonucleotides that are targeted to the liver *in vivo* effect sequence-specific antisense modulation of their target 35 gene in the liver *in vivo*, irregardless of the point of attachment of the cholesteryl moiety. Taken together, these findings provide the basis for a method of preferentially

targeting a biologically active antisense oligonucleotide to hepatic tissues in mammals, and thereby modulating the expression of a gene in the liver of a mammal, by conjugating the oligonucleotide to a cholesteryl moiety and administering
5 the cholesterol-oligonucleotide conjugate to a mammal.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANTS: Manoharan, Muthiah
Cook, Phillip D.
Bennett, C. Frank
- (ii) TITLE OF INVENTION: COMPOSITIONS AND METHODS FOR
ENHANCED BIOSTABILITY AND ALTERED BIODISTRIBUTION OF
OLIGONUCLEOTIDES IN MAMMALS
- (iii) NUMBER OF SEQUENCES: 63
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Woodcock Washburn Kurtz Mackiewicz
and Norris
 - (B) STREET: One Liberty Place - 46th Floor
 - (C) CITY: Philadelphia
 - (D) STATE: PA
 - (E) COUNTRY: U.S.A.
 - (F) ZIP: 19103
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.25
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
 - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: Lucci, Joseph
 - (B) REGISTRATION NUMBER: 33,307
 - (C) REFERENCE/DOCKET NUMBER: ISIS-2707
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: 215-568-3100
 - (B) TELEFAX: 215-568-3439

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 11 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

GGCTGACTGC G

11

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

CTGTCTCCAT CCTCTTCACT

20

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

TTGCTTCCAT CTTCTCGTC

20

(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

TGGGAGCCAT AGCGAGGC

18

(2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

UGGGAGCCAU AGCGAGGC 20

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 16 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

TCCAGGTGTC CGCATC 16

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 17 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

GGACCGGAAG GTACGAG 17

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 17 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

CCTGGCCTTC CATGCTC 17

(2) INFORMATION FOR SEQ ID NO:9:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 17 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: RNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

CCUGGCCUUC CAUGCUC

17

(2) INFORMATION FOR SEQ ID NO:10:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 12 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

CCCAGGCUCA GA

12

(2) INFORMATION FOR SEQ ID NO:11:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 12 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

GAGCUCCCAG GC

12

(2) INFORMATION FOR SEQ ID NO:12:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 12 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

CAUGCUGCAGCC

12

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

GCCTTTCGCG ACCCAACACU

20

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 10 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

GCGTGUCTGCG

10

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 18 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

UGGGAGCCAT AGCGAGGC

18

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 18 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

TGGGAGCCAU AGCGAGGC 18

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

UCTGAGTAGC AGAGGAGCTC 20

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

UGCCCAAGCT GGCATCCGTC A 21

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

UGCGTTTGCT CTTCTTCTTG CG 22

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

UGCATCCCCC AGGCCACCAT 20

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

UCCCGCCTGT GACATGCATT 20

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

GUTCTCGCTG GTGAGTTTCA 20

(2) INFORMATION FOR SEQ ID NO:23:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 19 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

UUGGGAGCCA TAGCGAGGC

19

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 12 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

CCAAGCCUCA GA

12

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 12 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

CCAGGCUCAG AT

12

(2) INFORMATION FOR SEQ ID NO:26:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

UGCCCAAGCT GGCATCCGTC A 21

(2) INFORMATION FOR SEQ ID NO: 27:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 27:

GAGCCGCTAC TCGAATGAGC 20

(2) INFORMATION FOR SEQ ID NO: 28:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 28:

GTTCTGGCTT CCGTTGCACC 20

(2) INFORMATION FOR SEQ ID NO: 29:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 29:

CCCGGCCCGG ATTGACTGAA 20

(2) INFORMATION FOR SEQ ID NO: 30:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 30:
CCATCCCGAC CTCGCGCTCC 20

(2) INFORMATION FOR SEQ ID NO: 31:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 31:
CGGTCCCCTT CAAGATCCAT 20

(2) INFORMATION FOR SEQ ID NO: 32:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 32:
CCCCTTCAAG ATCCATCCCG 20

(2) INFORMATION FOR SEQ ID NO: 33:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 33:
CAAGATCCAT CCCGACCTCG 20

(2) INFORMATION FOR SEQ ID NO: 34:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 34:
CCTGGTCATG TCTTCCTCCA 20

(2) INFORMATION FOR SEQ ID NO: 35:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 35:
CTTTGCCAG ACAGCAGCTG 20

(2) INFORMATION FOR SEQ ID NO: 36:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 36:
GTTCACTGGC GCTTTGTTCC 20

(2) INFORMATION FOR SEQ ID NO: 37:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 37:
TGAAGTTGAC TGAGGAAATG 20

(2) INFORMATION FOR SEQ ID NO: 38:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 38:
CTTGGAAGAG CCGCTACTCG 20

(2) INFORMATION FOR SEQ ID NO: 39:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 39:
GCCGCTACTC GAATGAGCGC 20

(2) INFORMATION FOR SEQ ID NO: 40:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 40:
GGAAGAGCCG CTA CTCTCGAAT 20

(2) INFORMATION FOR SEQ ID NO: 41:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 41:
CTCTGTTCTTCT TTAATTACGA 20

(2) INFORMATION FOR SEQ ID NO: 42:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 42:
TCCACTTGAT GATGTCTCTC 20

(2) INFORMATION FOR SEQ ID NO: 43:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 43:
CTATGATTTC TCTCCACTTG 20

(2) INFORMATION FOR SEQ ID NO: 44:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 44:
GGCAGTCAGT TACAGTCCAA 20

(2) INFORMATION FOR SEQ ID NO: 45:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 45:
TTTTAGCAAG GCAGTCAGTT 20

(2) INFORMATION FOR SEQ ID NO: 46:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 46:
TGCAAACATT TCAATACTTT 20

(2) INFORMATION FOR SEQ ID NO: 47:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 47:
AAGTTTAGTT TTATTATAGA 20

(2) INFORMATION FOR SEQ ID NO: 48:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 20
(B) TYPE: Nucleic Acid
(C) STRANDEDNESS: Single
(D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 48:
CACCACCCCC CTCGCTGGTC 20

(2) INFORMATION FOR SEQ ID NO: 49:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 20
(B) TYPE: Nucleic Acid
(C) STRANDEDNESS: Single
(D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 49:
CTCCCGCACA TCTCCGCGCC 20

(2) INFORMATION FOR SEQ ID NO: 50:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 20
(B) TYPE: Nucleic Acid
(C) STRANDEDNESS: Single
(D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 50:
GCCACCGTCT GCCCACTCTG 20

(2) INFORMATION FOR SEQ ID NO: 51:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 51:
GGCACGTGCA ATGGCGATCC 20

(2) INFORMATION FOR SEQ ID NO: 52:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 52:
CGGAGCCGCT TGGTGAGGAT 20

(2) INFORMATION FOR SEQ ID NO: 53:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 53:
AGCAGCATCA TTGGCGAGCC 20

(2) INFORMATION FOR SEQ ID NO: 54:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 54:
CGGCCATGGC ACCAAAGACA 20

(2) INFORMATION FOR SEQ ID NO: 55:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 55:
TGAAGTGAAT TGCCCCACGG 20

(2) INFORMATION FOR SEQ ID NO: 56:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 56:
GGGATGTCCG GTCGGGTGGG 20

(2) INFORMATION FOR SEQ ID NO: 57:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 57:
TGCCCACCAG AGCCAGCGTC 20

(2) INFORMATION FOR SEQ ID NO: 58:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 58:
ATGCCCAGGT GTGCTCGGAG 20

(2) INFORMATION FOR SEQ ID NO: 59:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 59:
GCCTCCTTTG CTGCCCTCAC 20

(2) INFORMATION FOR SEQ ID NO: 60:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 60:
TGGTGGACAG GCGGTGAGCA 20

(2) INFORMATION FOR SEQ ID NO: 61:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: No

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 61:
GGATCTTGAA GGGGACCGCA ATGGAGGAGC 30

(2) INFORMATION FOR SEQ ID NO: 62:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 62:
GTCCAACACT AAAAGCCCCA ATTAATACAG 30

(2) INFORMATION FOR SEQ ID NO: 63:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Nucleic Acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: Yes

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 63:
CTTACCCGCT TGTGTTGCTG 20